The Use of Explosives in the Tillage of Trees

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The Institute of Makers of Explosives
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Result of blasting ground when wet. One "pot hole" that was dug out. The walls were compacted enough to make a jug which would hold water. See page 32.

FOREWORD

THIS bulletin is published by the Institute of Makers of Explosives. It is not in any sense a piece of advertising or sales literature, but a careful summing-up of the known facts about the use of explosives in tillage of the soil of orchards.

In the following material uncertainities are eliminated as much as possible, in favor of facts established by actual experience. The information is classified and assembled so that any phase of it will be available easily and quickly. The bulletin is offered as a handbook or manual for fruit growers and farmers, gardeners, landscape gardeners, planters of home grounds and park makers, and as a textbook for students of agriculture.

Readers will find that the recommendations for the treatment of orchard soils are impartial, and that the part of the work best done with explosives is made particularly clear. The systems of soil management explained and outlined are practical and efficient.

Blasting Orchard Soil

The blasting of soil for tillage purposes was first tried more than a generation ago. Since 1900 the practice has become general in many sections of the country, particularly in those localities where orcharding is one of the main businesses.

The experiences of individuals and of official investigators have not been uniformly successful, though some remarkable results have been secured. When the idea of blasting soil for tillage first was freely offered to the public through advertising and the editorial matter of farm papers, many unjustified and foolish claims were made for it, and a great many mistakes were made in the actual blasting. These claims and mistakes are to be regretted, because they led to barren or damaging results and to uncalled-for criticism of proper blasting.

As a general statement of the proposition, it may be said that soil blasting is to be regarded largely as intensive tillage. Its benefits are derived from its physical breaking and mixing, opening and loosening of the soil, and show themselves in the form of better drainage, an increased supply of moisture in dry weather and better root penetration, and because of these, in the greater fertility of the soil.

This is the kind of result produced by blasting ground when it is wet, and sometimes by using too-quick acting an explosive in moist ground. The soil may be left in a worse condition than before the blast. See page 32.

The movement to blast soil at first popularly was called "deep plowing" or "plowing with dynamite," but most farmers have come to know that blasting soil is in no sense plowing it. Blasting will not replace ordinary plowing, nor can plowing be made to do the work of blasting.

The whole matter of orchard tillage and feeding must be taken up when soil blasting for the benefit of trees is to be considered intelligently. Blasting is but one spoke in the wheel. Much of the misconception which exists to-day regarding the value and benefit of blasting orchard soil is due to failure in grasping this fact.

The subject necessarily is a technical one, and this bulletin must deal with chemical and mechanical processes of the soil, using technical language to some extent. But as far as possible the matter is kept to broad general principles known and accepted by the great majority of agriculturists. The problem is to find out whether or not the kind of tillage which blasting gives will produce beneficial results, and produce them at a cost within the reach of commercial orcharding.

This hole was blasted out when the gound was much drier than at the time the crater in the other picture was blown open. Instead of the sides of the crater packing, they loosened and crumbled. But even this ground is not as dry as it ought to be. Also a subsoil blast never should blow out a "hole." See page 32.

What An Orchard Soil Must Do

When attempting to form judgment of soil tillage by blasting or to explain it, we should have clearly before us what we want to do with the soil and what we expect the soil to do for trees.

The purpose or idea of cultivation of orchards is to get profitable growth and yield from the trees. That is obvious. We want the greatest net profits possible under the conditions of each orchard. No one pursues a system of cultivation for the sake of the system itself, although the farmer or fruit grower does a great deal of tillage work rather blindly and without knowing just why he does it or understanding the soil processes he is dealing with.

But it is clear that to make trees grow and yield to their maximum capacity, requires so far as the soil is concerned, *enough water, sufficient of the right plant foods, and root anchorage and feeding space.* These 3 essentials for growth are delivered to trees only by the soil, and the work of the soil consists in supplying them to the trees. It must be in condition to deliver them.

The Soil Problems in Orchards

The Plant Foods

Correct fundamental education in the principles of soil nature and management is so universal nowadays that the primary facts regarding the growth of plants, and their feeding habits, need not be discussed in detail in this bulletin. It is enough for the purpose to say that every reader is presumed to accept the facts that the plant foods which have to be supplied are nitrogen, potash, phosphorus and lime. These are the only ones out of the 20 or more elements used by plants as food which run short in the soil, largely because they constitute the great bulk of the materials, aside from water, that are taken up by trees. The source of supply of these important elements are, on the one hand,

artificial fertilizers and manure, and on the other hand, the soil itself (though nitrogen is derived from the air by means of soil processes).

The water problem is not less well defined and understood. To some extent it consists in draining away surplus water from wet places and swamps, and in making certain of the effective drainage of all land during winter, spring and rainy periods of summer. To a greater extent it is a matter of storing enough water for the use of the trees during the growing season. No orchardist questions the fact that the lack of moisture very often is the limiting factor in growth and crop production. The moisture problem perhaps is the most serious one which fruit growers have to face.

Drainage and Moisture Storage

Root anchorage and feeding space (considered as one factor) give relatively less trouble than either a correct water supply or a proper supply of plant food. The latter factors must receive attention in all soils; the former only in certain soils of a hard or uninviting nature, or which are in bad condition owing to improper treatment. A light, porous, fertile soil offers no difficulties to roots in their penetration and food gathering, but a hardpan soil, a heavy clay or a cemented gravel soil does offer serious difficulties.

These two trees were washed out of the ground with a stream of water from a hose, in the fall of their first season after planting. The one on the left had been set in an ordinary hole, dug as usual. The one on the right had been set in blasted ground. The soil is typical redshale (Upshur), classed as clay loam. (New Jersey Experiment Station, New Brunswick, N. J.)

All orchardists agree that an extension of the root anchorage and feeding scope of trees is beneficial and desirable. Authorities continually remind us that we should drive the roots down away from the surface. One of the tests of the thrift of a tree is to examine its roots for the size and nature of their growth. If they are long, ropelike and few, the tree is starving. If they show as a mass of fibers growing from well proportioned main branches, which extend to a fair distance in every direction, the soil is full of the needed foods and moisture. Only trees which are firmly and deeply rooted will stand up against windstorms and under loads of fruit. It is largely to bring about the conditions outlined that orchard ground is cultivated.

Root Anchorage and Spread

What Soil Is

The material we call soil may be described as the outer layer of the earth. The soil includes loam, clay, sand, gravel, boulders and even ledges of rock. To limit the soil to the earth penetrated by roots would leave out other material underneath of exactly the same stuff. To limit it to what we call loose earth,

leaving out rock, shale and the like, would not be correct, since the rock and the soil are composed of the same elements. Often the point where "soil" begins and "rock" ceases is indistinct, as in the case of hardpan, for instance.

Origin of Soil

The loose earth, or ground, is only particles of rock that have been more or less changed by and mixed with the remains of plants. There was a time when there was no loose soil. The surface was rock. As the seasons passed, water dissolved and wore away particles of the rock. After a time mosses and rock plants appeared and sent their roots into crevices. The roots grew and helped to split off other fragments, and when the plants died their material gave off acids which helped the water to dissolve more rock and to dissolve it faster.

Frost and heat from the sun hastened the processes till the softer minerals separated from the harder ones, and what was not washed away by running water caved in and became mixed with dead moss and the decaying roots and stalks of grass and other plants.

This is soil at the present time, whether it is hard or soft.

Top-soil and Subsoil

The top-soil of cultivated land ordinarily shows a much more advanced stage of this breaking down process than the subsoil. The top-soil, which usually is the layer reaching to the furrow depth, generally is darker colored, from the greater amount of remains of plants it contains. It differs from subsoil in porosity, moisture content, bacterial activity and in other ways which will be explained fully farther along in this bulletin.

Whatever the difference, *it is largely a difference in the stages of decomposition or disintegration of the mineral particles*, and of the amounts of organic matter present. Both surface and lower soils are essentially of the same chemical make-up and they both may have come from identically the same kind of rock. The ground near the surface has been exposed to action of heat and cold and water and air and plants, and has been changed more than the ground under the surface. The more the soil is broken down from the original rock the finer the particles are, and in general, the more fertile it is.

The "Strength" in Soil

It is well at this point to call attention to the latent strength in the soil, to counteract any tendency toward the belief that you must put back in as much as you take out. The soil is not a sort of empty mill into which you pour plant food and take out crops. It is to a large degree an inexhaustible mine of many plant foods. As evidence, look at the immense growth that has arisen from it in moss, weeds and forests during the thousands of years past. If all this growth were piled up it likely would weigh as much as the soil itself to a great depth. In the soil and air now, waiting to be released and used, is substance enough to create food for all the people of the earth for years without end. In the soil of your own orchard and farm you likely have nearly all the plant food elements your crops ever will need. Make them available for roots, add to the supply the few that are short, and in crops you can profit from nature's riches as surely as though you were digging gold or coal.

The Relation of Tillage Blasting to Soil

That "tillage is manure" is no new thought. The phrase itself originated a great many years ago. The proof of its truth lies in the very nature of soil itself, which has been explained in the preceding chapter. Tillage, which is the stirring and mixing of soil, promotes and helps these natural processes which first changed the rock into soil, and which now tend to make the soil fertile.

Tillage Produces Fertility

A good, deep plowing, followed by thorough harrowing, opens up the soil so roots can penetrate it easily. It introduces air. It helps to maintain moisture in dry weather. It exposes a new part of the soil to frost and to sun. A new supply of the plant food elements which the soil contains is liberated, or it is better to say their liberation is hastened, and trees are given a better chance to grow.

The so called "run down" or "worn out" soils contain almost as much of most plant food elements as ever. But instead of the soil being soft and mellow, it has reverted and become harsh. A run-down soil shows under chemical analysis a composition not greatly different from what it does before becoming exhausted or after it is made fertile again. The only vital difference is the *state or condition* of the plant food elements.

Tillage alone of course will not keep land from running down. Plants also are needed for supplying vegetable matter in the soil. Their dead roots and stalks hold the particles of the soil in crumbs, increase its moisture holding capacity and help to maintain conditions under which further decomposition occurs continually. Without tillage the plants will not grow or at least will not become mixed with soil farther down than a few inches.

Cherry trees three years old, with corn intercrop, which certainly takes some plant food. The soil naturally is no better than in the other part of the same orchard, shown on opposite page, but it was well broken up with explosives.

Under wild or forest conditions with no tillage, the fertility of the soil is maintained and even increased, but the processes are very slow and the result is long in coming. In orchard soil the processes must be hastened so that the natural forest changes of 25 years take place in one.

When an explosion takes place in soil, the gases escape in all directions from the place where the dynamite or powder charge was located. Those gases which start downward and sideways soon curve upwards. They travel sideways several feet through the soil. They lift the soil in mass and make it break and crumble, and can be detected rising from the ground over a circle 10 to 15 feet in diameter about the position of the charge.

The gases of an explosive will rebound from a substance that is extremely hard or resistant, but they try hard to travel in a straight line in the original direction. When confined in hard soil, they strike against the resistance, and because the mass of soil is not firm enough to turn them aside, it is broken and crumbled. They smash right through compacted sections. This fining and crumbling action can be compared to the effect of pounding up a brick with a hammer. The tens of thousands of particles that had been clinging together in one hard mass are separated.

It is this fining and loosening which makes so valuable the particular kind of tillage which blasting gives. (It is intensive tillage—the kind which is "manure.") In modern agricultural practice intensive tillage is recognized as one of the best means of securing large crops—in fact, it is recognized as a necessity in orchards and in fields and gardens where intensive crops are grown. Blasting is tillage of the most intensive kind it is possible to secure by any practicable means.

The limit of plowing, even with deep tillage implements and subsoilers, is 16 to 18 inches. The shallowest blasting should reach to a depth of 36 inches,

In this orchard the trees are *seven* years old, but much smaller than the other, three-year trees. The fine growth of clover proves that top soil is fertile and in good condition, yet it does not grow trees as well as the blasted soil.

and the average work is done so as to reach to 48 inches or deeper. The real significance of such deep, intensive tillage is so far beyond the mere superficial appearance that it must be explained in separate chapters.

How Root Growth is Helped by Deep Tillage

A mature apple tree should have a root system spreading twice as wide as its spread of limbs, with some roots at least 10 feet deep, and a large part of the root system deeper than 2 feet. With roots less well developed and distributed, the tree is bound to suffer from lack of water, and plant food, and possibly from wind.

Depth and Length to Which Roots Grow

Fully developed peach trees have root systems smaller in proportion than apple trees. Pear, plum, quince, cherry, nut trees, citrus fruits, and the semi-tap root shade trees in mellow soil develop root systems not greatly different from apple trees in extent. Some ornamental trees, such as Norway pine and shagbark hickory, often grow half as deep into the ground as the trunk is tall. Grape vines have roots extending in every direction to a length out of all proportion to the size of the vines above ground.

These developments occur only when the ground is as loose, fertile and well watered as it should be. In orchards or hardpan soils and neglected soils. the roots grow out to a length less than the length of the limbs. They go down until they strike a compact layer of clay, a layer of hardpan, or the water table. Unless forced and coaxed down by cultivation, they grow up until you can see them where they bend above the surface.

The apple trees in these pictures were planted 19 years ago, in soil with hardpan about a foot under the surface. The tree at the right, in the picture, was planted without breaking up the bed with explosive; that at the left set in blasted ground.

Today some of the trees not growing in blasted ground are dead, while all those in blasted ground are living. Those in blasted ground average 25 feet high, and in unblasted ground 18 feet. The former trees have an average spread of limbs of 25 feet; the latter, 16 feet; while the trunks of the two sets of trees measures 3 feet 7 inches and 2 feet 3 inches, respectively. In the blasted ground the trees stand "shoulder deep," and over the unbroken hardpan the roots are raised above the surface, as the pictures show.

This is one of the most striking instances of the damaging effects of a hard and impervious soil that has ever been examined carefully and photographed. (Geo. W. Brown, Mount Cory, Ohio.)

The big root systems can be picked out by the appearance of the trunks and tops of the trees. No small, scrawny trees have well-developed and widely extending roots, nor will any large, thrifty trees have short and meagre roots. A tree that regularly grows and ripens a heavy crop of good sized fruit must have a big, deep root system. Any tree that does not cannot do the work. It follows, in view of these facts, that every orchard and ornamental tree should have roots extending as wide and as deep as possible. One or 2 feet deep is not enough. With roots only at such depths the trees exhaust the little bit of moisture within their reach during 3 or 4 weeks of rainless weather; or worse, they may be blown over by the first stiff wind.

Young trees have even greater need of proportionately big root systems than mature trees. Their roots need to go down 3 feet at least by the end of the second year after their planting and should extend laterally 6 to 8 feet then, even if the trunk is only 4 feet high. All that is said about root growth applies equally in the case of the newly planted tree and the tree that has been in place many years.

The Causes of Restricted Root Growth

The limiting factor as to depth of root growth may be some form of hardpan or cemented gravel, compact clay or other soil, poor drainage, or simply that the soil contains neither enough water nor enough available plant food.

Hard Soils Difficult to Penetrate

An idea of the difficulty encountered by roots in penetrating soil can be had by noting the method of their growth. A hair-like or pin point of a rootlet presents its tip in the direction it is growing. This new tip then expands like a bud in the spring, pushing back and lifting the soil or earth out of its way.

When the soil is soft and porous, the roots find little difficulty in penetrating it, because its minute air spaces serve as ready-made tunnels; but when the soil is compacted or cemented, as it is in hardpan, in hard gravel deposits, and in all harsh soils having little organic matter, the delicate, minute roots are compelled to do work which almost would defy a steel rod.

True hardpan is semi-rock. You cannot crumble off the edges of a chunk with your fingers. The softer type can be cut with a sharp knife, as clay can be cut, but the point of the knife cannot be forced into it without pressure or pounding. It is not surprising that such soil resists root penetration.

A hardpan layer, or one of clay, plowsole or other structure, can be compared to a plank floor underground. The roots will run along it in the softer soil, but they will not penetrate it. When a young tree is planted in a small hole dug in compact soil, it is, practically, in a wooden tub. The roots have to force their way through the hard sides in order to develop as the roots of a tree should.

Hardpan is Like Wood

The compact layer of soil may occur within 6 or 8 inches of the surface of the soil, or may be down a foot or 2 feet or more. Where within 2 feet of the surface, it often forces the roots to lift the crown of the tree entirely above the surface. If the entire root anchorage and feeding space of a tree is confined to the first foot or 2 of soil, it cannot grow or yield to anything like its maximum capacity.

To help to make clear the great difference in the case of root penetration

through hardpan, stiff clay or other tight soil, as against field soils in mellow condition, a statement of the amount of air space in soils may be of value. When a hardpan, clay or gravel soil has been thoroughly compacted by water or other agency so that the particles are packed as close as possible, *the air space (or pore space or porosity) is only 5% to 10%.*

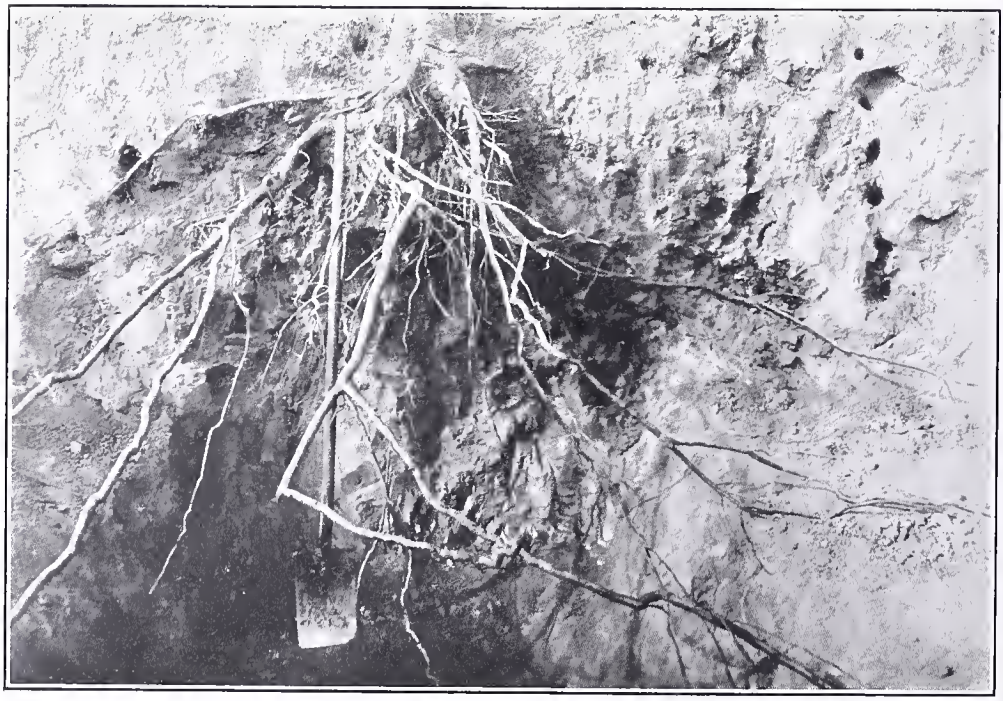
Porosity of Soils

The soil is 90% to 95% solid. This is the hardpan, cemented gravel and plowsole condition. But the average air space in soils in good condition is 6 to 13 times as much, as the following table shows:

Approximate Amount of Air Space or Pore Space in Soils in Good Tilth

Clean sand	33 Per Cent.
Coarse sand	40 " "
Medium sand	41 " "
Fine sand	44 " "
Sandy loam	51 " "
Fine sandy loam	50 " "
Silt loam	53 " "
Clay loam	54 " "
Clay	56 " "

The nature or character of the root growth is modified by the comparative mellowness of the soil. The ideal feeding roots, it is everywhere agreed, are fine, fibrous and not long. The main or anchorage roots should extend well



The nature of root growth of fruit trees depends on the condition of the soil in which they grow. The ground was dug away from the roots of two trees, leaving the main roots in their original positions—(See next page)

out from the tree and down deep, gradually tapering from a thick base to a slim point. All along them the tendril-like feeders should grow out like the legs of the so-called "thousand-legged" insects.

In a tight soil the main roots usually grow short and stubby, with few of the fine feeding roots. In a very poor soil the main roots lengthen into veritable ropes, traveling on and on in search of food. They are usually almost bare of feeders. Under any conditions of soil except that of the best tilth an excessive part of the strength of the tree has to go into root building and root penetration, rather than into food gathering. Too much time is consumed in growing the root. Five years may fail to develop a root system equal in food gathering capacity to a system developed in one year in soil of proper texture.

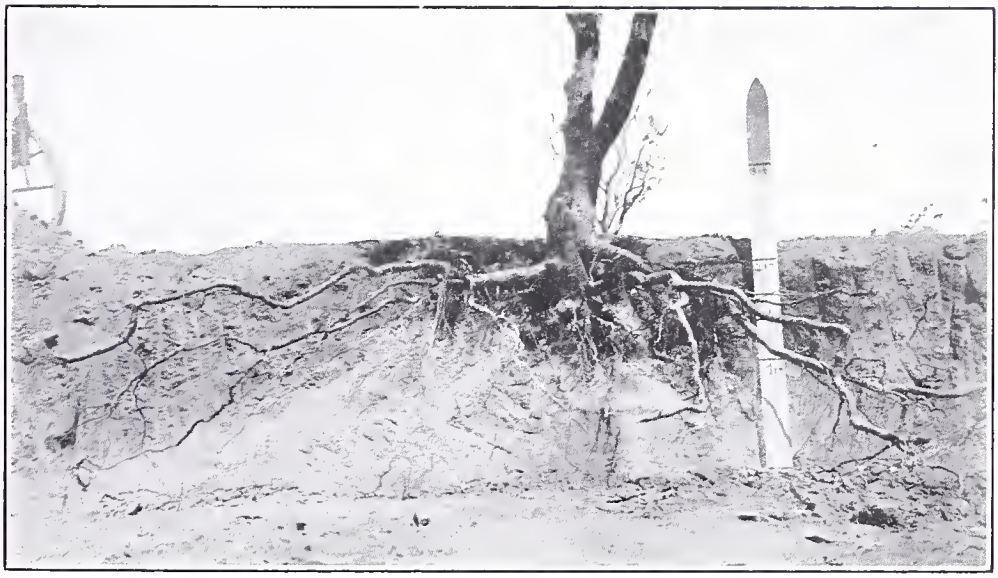
The limited digging usually done in making holes for planting trees serves to give the roots a brief start. The hole should be dug at least 3 feet deep and 4 feet square, but few indeed are the instances of the digging of such large holes in commercial orchard planting. The usual practice is to scoop out just enough ground to let in the severely trimmed roots to the required depth.

Tree Holes Dug by Hand

Quite often young orchard and shade trees are set in holes not more than a foot deep and 18 inches wide. The sides of the holes frequently curl the ends of the roots back like clinched nails. An examination of trees that have been dug up or washed out a couple of years after they had been planted in dug holes, shows that masses of matted and twisted roots have been confined in the hole that was dug, almost like the roots of a large plant in a small flower pot.

How to Secure Big Root Development

The way to do this is to break up the soil with tillage, and to make it fine and porous. Tillage with plows and cultivators can be extended to a depth



—Note how the hard ground under the one tree kept practically all its roots in the top two feet of soil. The soil under the other tree was lighter and more porous but not fertile, consequently the roots grew like long ropes, traveling many feet in all directions. Both are poor root systems.

of 8 inches without trouble. By using subsoil attachments and deep tillage disk implements 18-inch tillage is practicable. Where it is desired to go deeper, hand digging and blasting are the only means available. Hand digging of all the soil is impracticable in commercial orchards, but if the cost does not matter, the ground of home fruit gardens and lawns can be worked over by hand to a depth of 4 to 5 feet by digging wide trenches and shoveling the ground back from each new trench into the old one. This is a common practice in many European gardens.

Deep Tillage Insures Big Root Systems

Tillage by blasting is pre-eminently the most advantageous treatment for the soil that is hard enough to restrict root growth or to hold free water. In a previous chapter the action of a proper blast has been described. It is clear that the explosion, in breaking up the hardpan or the plowsole or the layer of stiff clay or cemented gravel; in opening cracks through the soil in every direction, and in crumbling and fining the earth to a depth of 4 or 5 feet or more, as you place the charge, supplies just the treatment needed. By no other practicable means can the soil be worked to an equal depth, and in no other way can even the top 2 or 3 feet of soil be worked so thoroughly at a reasonable cost.

After considering the foregoing facts the thinking man will need no concrete examples of better root expansion in well tilled soil to convince him that roots will develop when given the chance and the incentive. The illustration on page 6 shows this so well that every reader should look at it now. Two young trees were washed out of their beds. Both had grown one season. The root system of the one in blasted ground is about 4 times the size of the other, and it is of a better character.

Roots in Blasted Ground

In the orchard where these two trees are growing are many thousand set in blasted ground and a few hundred in unblasted soil. Not as many died as a result of planting each 1000 in the deeply loosened ground as of each 100 in the unbroken soil. The growth made by each class of trees up to the end of the second year after planting is shown in the pictures, which are of typical trees from each lot. (The Belmont Orchard Company, Charlotteville, Va.)

This example is not advanced as typical of all results. The growth that will be made by any tree cannot be predicted. Too many other factors aside from the condition of the soil enter into the matter. The fact that some trees in properly blasted ground have grown as much in 2 years as others in unblasted ground have grown in 4 years is no guarantee that all trees will do as well, or may not do better. If the blasting is not done right no benefit at all may be derived; indeed, there are cases on record where positive damage has been done to soil and to trees by improper blasting.

Amount of Increased Growth

There are but few soils in which intensive tillage of any sort will not help the root growth of trees. Among them may be mentioned loose, light sand, gravels and loams which are as porous and mellow as they should be without further loosening. The volcanic ash soils of some Rocky Mountain states need no deep tillage unless underlaid with more or less crusted lava.

Soils That Should Not be Tilled Deeply

Whether or not to blast loam soils to secure better root penetration depends on their character and condition. If they are deep, well drained and well supplied with humus, the chances are that little increase in root growth will be derived from any sort of deep tillage. But considerations in respect to moisture storage and the liberation of insoluble plant food nearly always call for tillage and yet more tillage. Roots of cover crops must penetrate the ground in order to keep soil fertile. Hence few soils aside from those named above will not be benefited by deep tillage.

Correct methods of doing the blasting to put soil into proper condition for root development and for other purposes are described on pages 32 to 39. On page 41 you will find a discussion of the length of time one thorough breaking up of the soil may be expected to last, and of how the needs of trees may be met both at the time of planting and years later, when the roots have extended themselves many feet in all directions.

How Soil Water is Governed by Deep Tillage

In every orchard soil the water problem is two-fold. Surplus water must be drained away and sufficient moisture for use of the trees during dry weather must be stored. Both purposes are served by tillage in ways that are made plain in the following explanations.

The drainage must be effective enough to take away the excess water quickly, but the flow of water must not be so fast as to leach or float away much plant food. Whenever the excess water is permitted to run over or through the soil in trickles, it leaches out available plant food. It should filter away—without delay or damming back, but still filter—through beds of fine, granular soil.

Leaching

The water should escape at a lower level into a ditch or into a loose layer of gravel or sand that will carry it away. In orchards the level of standing water in the soil must be well below the depth of root penetration if the trees are to grow and yield well.

Conditions Necessary for Drainage

To a great extent the drainage problem is to put the soil in condition by tillage to act as a filter bed. The soil must be kept loose enough to let the water seep and percolate through. Layers of tight soil, such as compact clay

Proper Drainage

or hardpan, hold the water as though it were in a tank or a pan. It cannot escape except by evaporation. Such tight soil must be broken up to a depth that will permit the lowering of the water-table below proper depth for root growth.

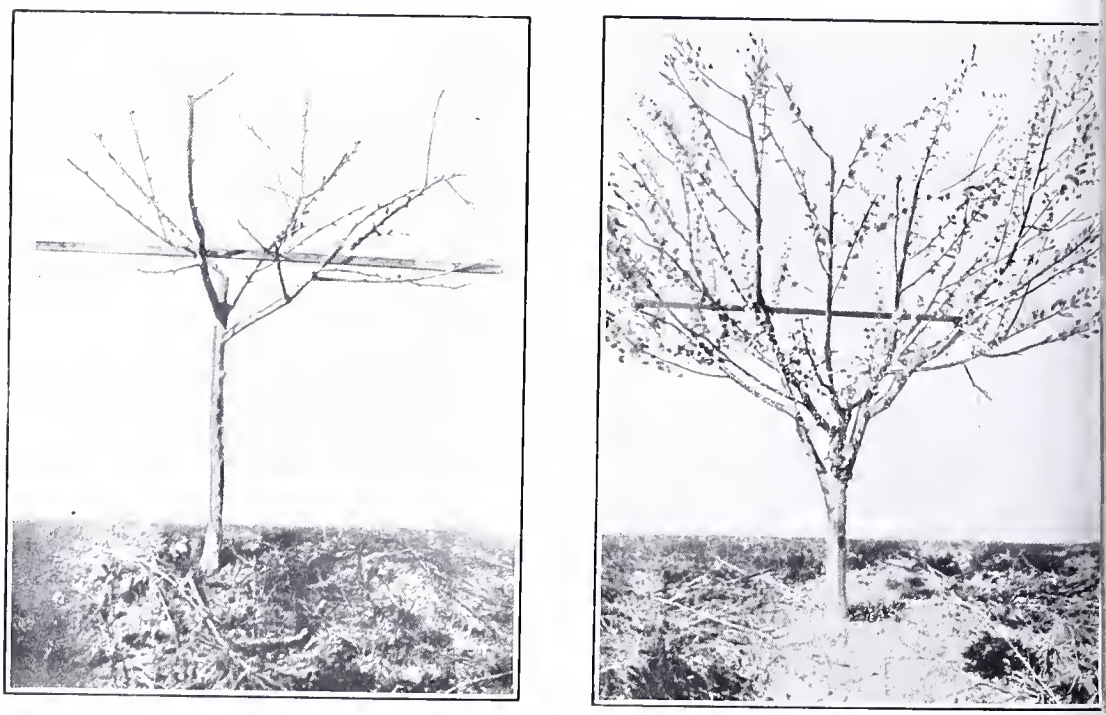
If the layer is thin—say only a couple of feet through—all of it can be reduced to fine particles. When it is thicker than 4 or 5 feet it cannot be broken entirely through to softer ground below except at prohibitive cost, and the effort should be to create a zone of proper condition in the top 4 or 5 feet of the ground. From this the water should drain away into ditches.

Even in soil containing no clearly defined hardpan, the general texture and condition may be such as to make drainage poor. Tillage will remedy this condition, by opening up and fining the soil so that water can move about in it freely.

The statement of the porosity or air space of soils in the chapter on root penetration (page 13) will be interesting in this connection. In a hardpan or thoroughly compacted clay there is an average pore space of only 5% to 10%, but when the same soils have been reduced by thorough tillage to a proper condition of tilth they contain upwards of 40% on the average, or 6 to 13 times as much pore space. In other words, nearly half of the bulk of the soil is air space, open to the free movement of water. Naturally such well-tilled soils are well drained.

Moisture Storage

The amount of water that in a dry season must be stored somewhere in the soil, available for the trees, can be stated with a fair degree of accuracy



A direct comparison in growth. The superior soil conditions brought about by intensive deep tillage are responsible for the gain of the one tree over the other. Such marked results are not always produced by blasting however—only when the soil is of a nature and in a condition to respond quickly and heavily to the action of air moisture and bacteria. (Auburn, Ala.)

in terms of inches in depth. It must be based, of course, on the needs of the crop of twig growth, leaves and fruit. For each ton of material grown (dry) it is safe to say that at least 3 inches of water will be used by the trees. If the orchard crop weighs 5 tons to the acre, which probably is less than the average, the amount of water required is 15 inches in depth over the acre. This amount meets only the actual needs of the trees, and does not allow for much waste through surface evaporation.

Amount of Water Used by Plants

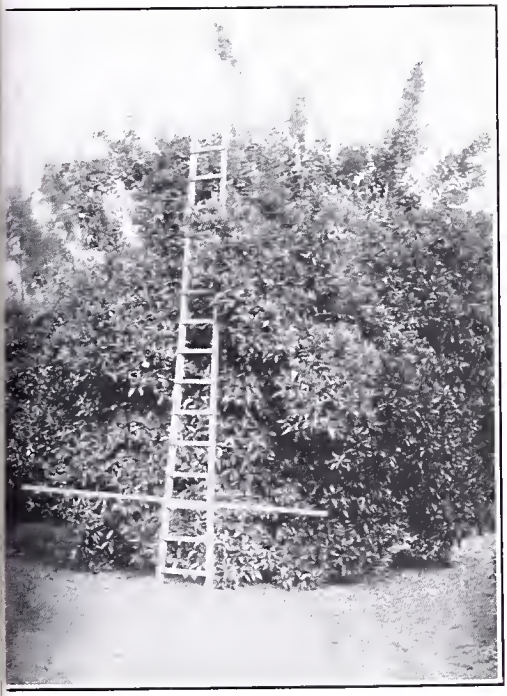
Fifteen inches of water is the net amount that will be required to make the growth and yield of the trees. Less water available for the roots will mean decreased growth and fruit production. If irrigation is not practiced, the one safe procedure is to store the required amount of water in the ground, for rainfall is uncertain, and cannot be depended on.

Amount of Water Stored by Soils

The capacity of a well-drained soil to hold water in a condition in which it is useful to trees depends on its structure and condition. Laboratory tests of average field soil in excellent tilth have shown in the first 4 feet down from the surface the amounts of water given in the table below.

Amount of Water Contained and Useful in Different Soils When Tilth is Good—Top 4 Feet Fully Loaded

	Amount water (inches deep)	Water weight	Unavailable	Inches available
Coarse sand	7	11%	3%	5
Light silt loam	14	21	10	7
Fine sandy loam	11	18	5	8½
Clay	16	30	17	7½



The superb soil conditions produced by intensive deep tillage are nowhere of more value than in orchards of citrus trees. These two trees, both Valencia orange, both 15 years old, were planted side by side. The one in unbroken soil is only 8 feet high. The other is nearly three times as high and more than twice as broad. (E. C. Stanzen, Santa Ana, Cal.)

These soil types are named for purposes of illustration. The moisture content of other soils can be judged from these figures.

The figures in the first column indicate that clay and light silt loam to a depth of 4 feet might contain enough water for average crops of fruit, while in coarse sand and fine sandy loam trees would run short. But only part of the water can be used.

Not All Soil Water Can Be Used

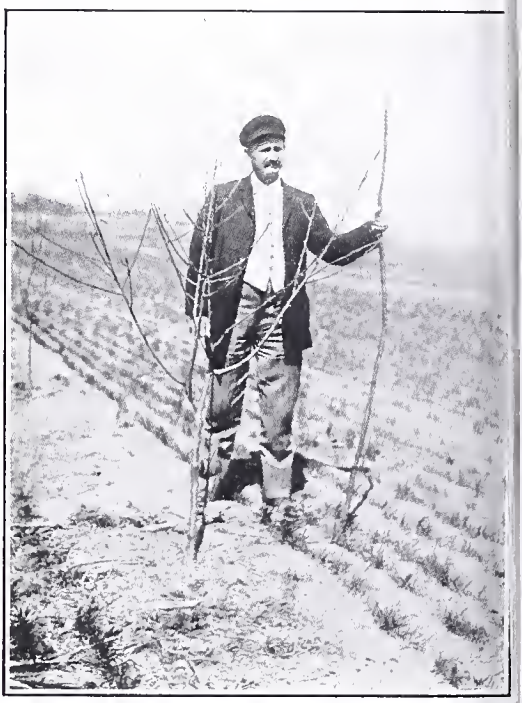
In clay soil, for instance, trees will wilt when the ground still contains about 17 per cent. of water. This leaves only $7\frac{1}{2}$ inches in depth of water out of the total supply of 16 inches when the soil is filled to capacity, that the trees actually can use. The proportion of water that can be used in the other soils is shown likewise in the table.

It follows that all the water that can be stored in the top 4 feet of any soil is not enough for a fair crop of fruit. The supply must be increased. The trees must get a part of their supply from the subsoil beneath the 4 foot level. This brings us to a consideration of the manner in which water is stored in the soil and the ways in which it moves about. In previous reference to the pore space or air space in soil (page 11), the free drainage of excess water was mentioned.

How Water is Stored in Soil

Water which will percolate and seep down through the pores of the soil owing to the action of gravity is harmful to all fruit and ordinary shade trees. The roots cannot or will not take it up in this form, and are damaged by it.

The only form in which roots take up water is when it clings to particles of soil as films. This is called capillary water, because it is held to the particles by capillary force. What this force is and the form in which the water is held can be illustrated better than described. Put your finger in water and



A tree should show greater proportionate superiority owing to intensive deep tillage in its second year than its first after planting. This is on account of the roots penetrating deeper and wider in the broken soil, and the increased plant food released and made available. Tillage merely starts the beneficial soil processes. Time is needed before the results show. The two trees shown here demonstrate this truth. Both are at the end of their second year's growth in their present beds. One bed was blasted; the other not. (Fred W. Miller, Millersburg, Penna.)

it comes out wet. Put it in quicksilver, and it will come out dry. Some of the water is held to the skin by capillarity, but none of the quicksilver is so held.

After excess water has drained away from the soil particles, they are wrapped in films of water which can be more correctly called moisture. This moisture is held to them by capillarity until it is taken away by evaporation or by roots.

If one particle should happen to have less moisture than its neighbors, capillary force causes some of the bigger supply to creep from surface to surface till the amount is equalized throughout the soil. The movement of capillary moisture is not limited to the one direction—downward—as free water is limited. In this form moisture moves upward and sideways as well. The movement can be illustrated by the movement of oil in a lampwick, or of ink in a blotter.

Now the movement of capillary water toward the surface from a depth greater than 4 feet is free and abundant when soil conditions are right and there is an abundant supply below. It, however, depends on the fineness and arrangement of particles and the pore space of the soil. The soil must be fine; the particles must touch one another; but they must not be so packed or jammed together that the pore spaces are squeezed shut. If the particles are round, they should touch one another only at minute points on their surface, as apples touch when properly packed in a box. The logical way of feeding moisture to trees or plants is to send the roots down after it. Capillary movement, however, brings the moisture to the roots as they use up the supply they are in contact with.

The reason behind the necessity for a comparatively loose condition of soil is easy to see when we remember the films in which moisture is held. Reduce the surface space of the particles and we reduce the surface area which can carry moisture films.

The size of the particles governs directly the extent of the surface area in a given bulk of soil, and consequently the amount of film moisture it holds.

Film or Capillary Moisture Supply

As it is illustrated often, a solid rock in the form of a cube, measuring 3 feet high, 3 feet wide and 3 feet thick, has 54 square feet of surface area. Reducing such a rock to pieces measuring an inch on a side increases the surface exposed to nearly 2000 square feet. Reducing the pieces to the size of soil particles increases the area in proportion.

As applied directly to the soil, the facts regarding the number of particles and their surface area are striking and wonderful. The table below gives the figures.

Number of Particles and Area of Their Surfaces in Different Soils in Good Tilth

Soil	Number particles per pound of soil	Sq. ft. surface area per pound of soil	Sq. ft. surface area per cu. ft. of soil
Coarse sand	1,326,600,000,000	405	40,500
Medium sand	1,724,700,000,000	473	44,500
Sandy loam	2,914,000,000,000	816	66,600
Silt loam	4,287,000,000,000	1340	104,000
Clay loam	6,811,400,000,000	1825	136,500
Clay	8,231,100,000,000	2000	142,000

The significance of the figures in the last column will be plainer when it is recollected that an acre contains about 43,000 square feet. Each cubic foot of medium sand contains about an acre of surface of particles on which moisture

film can be held, and each cubic foot of clay contains upwards of 3½ acres of such surface. Therefore an acre of soil to a depth of a foot may contain upward of 43,000 to 140,000 acres of moisture film when in proper condition.

The figures are illuminating in respect to the varying moisture-holding capacities of different soils. Sand has less than one-third of the capacity of clay. These differences should be kept in mind.

The Moisture Supply Depends on Depth and Thoroughness of Tilth

The figures for the amount of water soil can hold are based on soil in first-class condition of tilth, with normal porosity of 30% to 50% and with the usual amount of organic matter. Soil that is compacted, cemented, run together or lacking in humus will not have anything like the stated amounts. Also the movement of water—the drainage of free water and the movement of capillary water in dry weather—will be restricted very greatly.

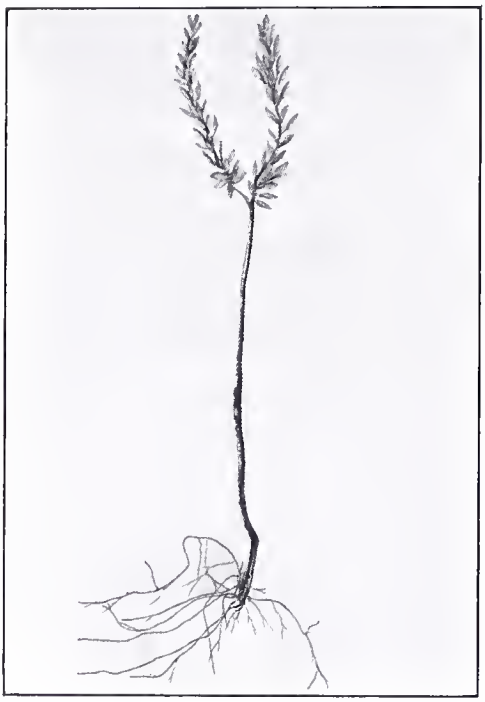
Good Tilth

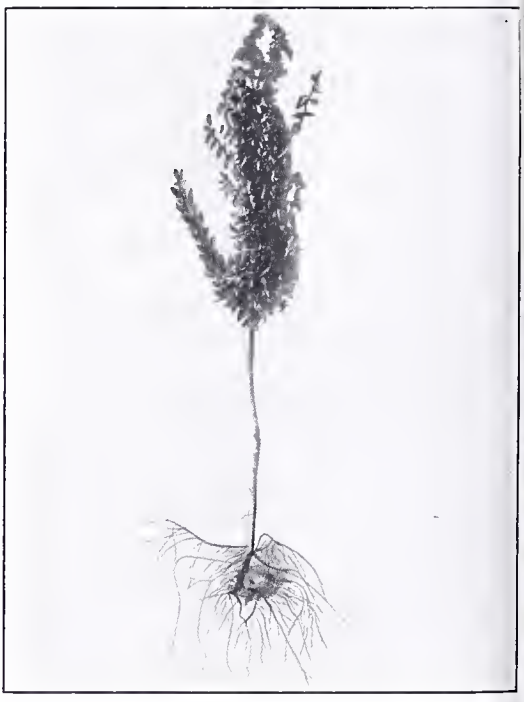
Emphasis must be placed on this matter of organic material in the soil. It constitutes one of the most important elements that go to make good tilth. If organic matter is lacking the soil will run together and within 2 or 3 years will become harsh and unpleasant in spite of the most intensive tillage.

Organic Matter and Moisture

The way to insure the necessary 15 inches or more of net depth of water needed to grow full-sized crops is to fine and loosen the soil thoroughly to a depth of 4 feet or more in order to store the maximum of moisture, and then have the ground below this depth in such condition that capillary moisture will rise without restrictions.

Tillage must be thorough and deep to promote drainage and to put the





One tree grew from spring to fall in blasted ground; the other alongside it in unblasted ground. The trees both are Yellow Transparent, 2-year when set out, and of equal size then. (E. G. Sexton, Canton, Ga.)

soil into condition to store sufficient moisture. If it is not the soil below the furrow depth becomes compacted and hard. The particles of soil run together till their water-holding capacity is only a faction of what it ought to be and can be under normal conditions of tilth.

Deep Tillage Demanded

Something can be done toward increasing the moisture storage capacity of soil by breaking to a depth of 16 or 18 inches with subsoil plows and deep tillage implements. But the execution done by proper blasting is better in proportion to its increase in depth.

Subsoil Plowing

Thoughtful orchardists will see that there is no practicable way of getting the soil worked and loosened at sufficient depths other than by blasting it. Blasting will do it—and in connection with regular and cover crops to keep up the organic matter will insure each season a supply of moisture sufficient for heavy crops in dry weather.

Blasting Soil

In case layers of hardpan or clay interfere with the movement of water, they should be broken up. Soil should be examined thoroughly for any such conditions.

The conservation of a moisture supply by shallow surface tillage is a general practice. It need not be described here other than to say that a 2 or 3 inch layer of loose, dry soil or dust will isolate the moist soil beneath and prevent the escape into the air of the water it carries. Deep tillage will help to provide the storage of a supply of water, but it will not conserve it. This moisture conserving (mulching) tillage on the surface is absolutely necessary.

Surface Mulch Required

But no amount of surface tillage will conserve moisture that is not stored in the soil. Enough rain falls during the growing weeks of some seasons to supply the needs of heavy crops, but every orchard in which the soil is not deeply tilled is bound to suffer from drouth frequently. The outstanding fact is that deep tillage is required before an adequate supply of moisture can be assured every summer.

How Deep Tillage Increases Fertility

The proper proportion for the different plant foods previously mentioned in the soil cannot be stated exactly, because different plants and trees require different amounts. A slight excess of any element will do no harm.

The so-called chain theory of plant food needs has been proved true so often and so extensively that it is to be considered no longer as a theory, but a fact. Briefly, this rule is to the effect that the thrift or growth of a tree or plant is governed by the amount of that plant food in which the soil is weakest, proper balancing considered.

Balancing Plant Foods

If a certain soil contains—we will select arbitrary figures for the sake of illustration—in each cubic foot 6 units of nitrgoen, 10 units of phosphorus and 20 of potash, while the need of the crop grown in this soil is 10 units of nitrogen, 20 of phosphorus and 12 of potash, the crop will not be a full one. It likely will be three-fifths of normal size, because growth will be held down by the lack of enough phosphorus and nitrogen. The over supply of potash in the soil is of no use because one plant food cannot be used to any practicable extent in place of another.

This one illustration is enough to make clear the idea of the necessity for having all plant foods present and available in abundance. There is nothing

mysterious in the fact of a crop failure, nor need there be much doubt about what constitutes proper fertilizing of land.

But knowing what elements of food are needed is only half the battle. It is equally important to know *where to get the necessary material and how to make it available for roots, certainly, cheaply and quickly.*

Plant Foods of the Soil As stated on page 7, the usual orchard soil contains an abundant supply of available plant foods, excepting only of nitrogen, phosphorus, potash or lime, which may or may not be present in sufficient amounts.

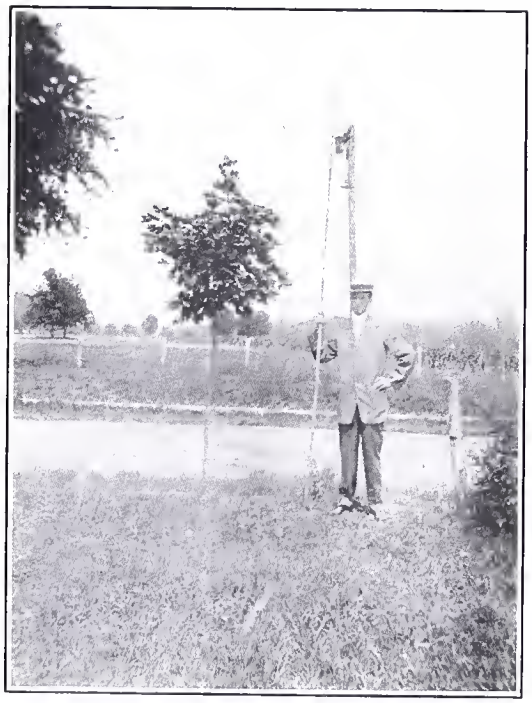
The nitrogen can be secured in unlimited quantities from the air and put in the soil by proper use of legumes.

The lime must be added in the usual way.

The Phosphorus and Potash Problem

A chemical examination of your soil, to a depth of one to 6 feet or more, if it is clay, loam or sand, likely will show figures for the amount of potash and phosphorus present that may surprise you. To make them apply more easily to the usual field condition, the following data are based on an acre, but of course do not apply accurately to all soils.

Amount of Phosphorus and Potash The amount of potash in the soil of "new ground" to a depth of 7 inches, the usual furrow depth, will run as high as 60,000 pounds. It may be as low as 20,000, but it will average up to 40,000 to the acre. The soil to a depth of a foot, therefore, contains more than 100,000 pounds, or 50 tons of actual potash. To a depth of 4 feet the amount is 200 tons to each acre.



The growth of shade and ornamental trees is governed by exactly the same principles as that of orchard trees. They must have enough moisture, nitrogen, potash and phosphorus, and must have root anchorage and feeding space. In a yard or lawn the soil conditions are such usually as to be benefited particularly by the intensive deep tillage given by blasting, as these two pictures demonstrate. (St. James, Mo.)

The amount of phosphorus is smaller, but still is formidable. It runs as high as 25,000 pounds to the acre in 7 inches deep of soil in some of the better new lands, falling to only a few hundred pounds in poor lands. In all new lands in good tilth it will average around 8,000 pounds to the acre in the clay, and about 2,500 pounds in loam. In soils that are run down the phosphorus usually is used up till less than 1,000 pounds and sometimes only 200 pounds to the acre remains in the top 7 inches.

Taking the above average figures, each foot deep of fertile loam contains upward of 2 tons of actual phosphorus and each foot of clay, 8 tons. Four feet of soil over an acre contains 8 tons and 32 tons respectively.

Amount of Plant Food Used by Trees

The different fruits and other crops require varying amounts of plant foods, as mentioned at the beginning of this chapter, but a sufficiently clear idea of their average requirements can be secured by examining the demands of a wheat crop. Wheat requirements are not essentially different from those of apple, peach and pear trees.

Trees use the most of their potash and phosphorus in growing leaves, twigs and bark, and little in growing the fruit. The food elements in the leaves of trees, of course, are returned to the soil each autumn, but those used in making wood are permanently removed from the soil.

Erosion and leaching take away some plant food. This loss, of course, must be added to the amount carried away in crops. Tests have shown the loss to be about one-eighth of the amount consumed by average crops. Nearly all of this comes from the few top inches of soil. The top inch or two of some soils is leached "dead."

The store of phosphorus in the soil, we have seen, is much less than that of potash—averaging one-half to one-fifteenth as much—but the amount consumed and carried away by crops is nearly equal. Therefore, the phosphorus supply is subjected to a much greater drain in proportion, and will be exhausted in much less time. In many soils it is already seriously depleted, if not practically exhausted.

Natural Plant Foods Insoluble

In the chapter which described the formation and nature of soil, it was pointed out that heat, cold, water, air, bacteria and other natural agencies had manufactured the loose earth commonly called "soil" by disintegrating and

It is extremely important that an evergreen tree should have its roots below frost-line, on account of the evaporation of water from its needles during the dormant period. Cut off evergreen roots from moisture and they quickly dry out. The resin in their sap hardens. When this happens the tree is doomed, because the sap never again will soften and flow.

decomposing rock. That is, they broke it down from solid rock to the softer stage, of more or less fine particles.

Now, plants require their food to be dissolved in water before the roots can take it up. They take their potash and phosphorus and nitrogen and other foods as soup instead of solids. *But these food elements will not dissolve in water as they exist in the soil.* They first must go through certain chemical changes.

The agencies which produce the changes are the same ones which brought along the processes of decomposition of the original rock so far—water, air, bacteria and the others that have been named. To these may be added organic matter and lime. In the ordinary course of events in an unworked soil, such as in a forest or a field only plowed, the subsoil is but little disturbed and none of these agencies is permitted to do much work. An occasional root penetrates deeply, a mole or a squirrel or other animal may dig a tunnel, producing the conditions necessary for the liberation of the insoluble food. But in the main the freeing of the locked-up elements takes place at a very, very slow rate.

The problem of the orchardist is to hasten the processes of liberation so that the natural chemical changes of dozens of years will take place in one season. To accomplish this he has only to expose the particles of the soil to the action of his helpers, the water, air, lime, organic matter and bacteria. Moisture liberates plant food directly by dissolving such of it as will yield, but whenever there is excessive free water some of the food that is liberated is carried away with the surplus water that drains out of the soil and some more of it is changed back to unavailable forms.

Liberations of Natural Plant Foods

The most rapid liberation of insoluble foods takes place when the water in the soil is limited to the moisture held by capillarity. This water wastes none of the material it frees. Each soil particle contains some of the plant food and its film moisture extracts this and holds it until the roots get it by taking up the moisture.

This picture is included to show what may be considered as standard good growth. The tree, a Stayman apple, was planted in Maryland, near the Pennsylvania line, late in April. The photograph was made in September. The average growth of branches is 18 inches. (Garacove Farm, Northeast, Md.)

Air produces oxidation of the insoluble elements (as rust) in connection with a proper supply of moisture. Organic matter contains acids, which, released in the decomposing of the roots and leaves, act chemically on the locked-up food in the particles and free some of it. Lime acts to some extent in a similar way. But by far the greatest amount of liberation of the insoluble elements is due to the action of certain beneficial bacteria.

These beneficial forms of animal life cannot exist in soil that contains little air, or which has either too much or too little water, or little vegetable matter. Nor can they exist when the soil lacks lime. As soon as the soil is made normally porous, as described on page 11, the excess water drained away and a proper supply of moisture held as films about the particles, and when vegetable matter in the form of roots and stalks of plants is introduced, the bacteria begin to multiply and become very active. Under favorable conditions they are able to liberate more insoluble potash

and phosphorus in one or 2 years than has taken place in 100 years without them.

On the majority of farms some potash and phosphorus has been added to the top-soil in commercial fertilizers and manures, but the quantity is small compared to the original natural supply.

Recapitulating, the liberating of the insoluble potash and phosphorus that is in the deeper soil calls for the introduction of air and the presence of capillary moisture and plenty of organic matter. The only way in which the moisture can be stored and maintained in dry weather, is by fining and loosening the soil, which automatically brings the necessary porosity and air supply and conditions for root penetration.

The presence of a large weed and grass growth proves that the soil is fertile. It is not detrimental, but helpful, in the orchard after July. Under a system of shallow surface tillage during the spring months and intensive deep tillage every few years the food supply will be kept up largely by nature.

The difficulty in an unworked soil is to keep plant foods, particularly potash and nitrogen, in an available condition. When bacteria are not active, the available fertility reverts to its original insoluble state very quickly.

Once the soil is loosened, cover crops should be planted immediately so that the ground will be filled with roots to a depth of 4 or 5 feet. This is the only way raw vegetable matter can be distributed below plow depth. Tillage itself will not make the soil granular and mellow. That is a result which comes about after proper conditions are established. The proper plants to select for this purpose are those which have abundant roots. If the regular crops meet these specifications they will do.

Cover Crops

Weeds make good cover crops. Some of the more common weeds, such as wild carrot, ragweed, smartweed, mullen and others have the power to take from soil—even sandy soil—larger quantities of potash than cultivated grasses or crop plants do. They break down insoluble plant foods and store a heavy percentage in roots, stalks and leaves. On their return to the soil these stalks and roots serve the double purpose of organic matter and of carriers of avail-

able food. Throughout preceding pages no attention has been given to this power of plants to act as miners and refiners of insoluble native food elements in the soil. Their action in liberating locked-up elements is considerable.

To discuss the methods of loosening and fining the soil would be only to repeat what has been said in previous chapters. It can be done with a certain degree of effectiveness with deep tillage implements and subsoil plows, but it can be done better by blasting. The explosives reach down where the tools cannot reach—with a thoroughness beyond comparison.

Methods of Tillage

The vital point is to get the subsoil at depths below a foot worked thoroughly. To depend on the soil above this is to send a boy to do a man's work. The use of 3 or 4 feet of soil by the roots, rather than 7 inches, or one foot, obviously is bound to be of great advantage unless the top foot is exceptionally rich. The rate of liberation of the insoluble elements from one foot of soil seldom is great enough to provide food for the full crop. From 3 or 4 feet the amount liberated at the same rate will be 3 or 4 times as great, and is more likely to satisfy the trees.

Soil

Lime improperly applied will cause the soil particles it comes in contact with to give up all their plant food, and it will decompose organic matter very fast; hence its use should be planned carefully. Burned lime, either steam slaked or air slaked, is much more violent in its action on the soil particles than ground limestone. The latter is mild and slow when applied in any quantity; the former should be strictly limited in quantity and should be thoroughly and evenly distributed and mixed with the soil.

In soil that is properly porous and fine, lime applied to the surface is carried all through the ground to a depth of 3 or 4 feet within a comparatively short time. In compacted soil, as when the ground under the usual furrow depth has not been broken up for years, lime organic matter and rainfall—and roots—are kept near the surface while ground moisture and seven-eighths of the plant food that ought to be used are kept below, safely and uselessly—stored for the benefit of future generations of farmers.

This peach tree is a product of intensive deep tillage. It was planted in its present bed one year and six months before the picture was taken, consequently it made the growth you see in two seasons. (R. C. Walton, Fruit City, Mo.)

The Nitrogen Problem

The relation of deep tillage to the supply of nitrogen in the soil is not so direct as to the supply of phosphorus and potash, but none the less definite. Tillage, together with proper accompanying orchard practices, will keep the soil supplied with all the nitrogen the trees need.

In Chile are deposits of nitrogen-bearing mineral, which, in the form of nitrate of soda, is used in

fertilizers to carry nitrogen into the soil. Other commercial fertilizers bearing nitrogen are cotton seed meal, bone, meat scrap and dried blood. In them the nitrogen costs 12 to 40 cents a pound at usual market prices. This nitrogen is an exceedingly expensive plant food compared with phosphorus, and compared with the value of the growth it makes, though its use in these high-priced forms may be profitable when well directed.

Nitrogen in Commercial Fertilizers

A cheap source of nitrogen, however, is the air. The air is 75% nitrogen. Over each acre of ground there is an unlimited supply of it. The cost of getting nitrogen from the air is small. In many cases enough other benefits are derived from the process to give a profit in addition to the nitrogen. Probably it is better to say that the processes which produce the nitrogen are required anyhow in nearly the same form to establish and maintain good soil structure and texture.

Nitrogen in the Air

This atmospheric nitrogen gets into the soil as one of the components of organic matter—in leaves, stalks, roots and seeds. The plants which are richest in nitrogen are the legumes—clovers, peas, beans and vetch. But all plants contain some of the valuable substance.

The amount of nitrogen needed by orchards will likely be 50 to 150 pounds a season. Heavy crops of corn require 150 pounds. Light crops of wheat require as low as 48 pounds. The cost of these quantities of nitrogen if all is bought at current prices in commercial fertilizers is prohibitive.

Amount Used by Orchards

In the usual soil there is but little nitrogen. A chemical analysis likely will show a few hundred pounds to the foot in depth over each acre, though soils unusually rich in organic matter may contain several thousand pounds. But unlike insoluble potash and phosphorus, on the ordinary farm nitrogen soon becomes soluble in the top foot of soil. When the leaves, stalks and roots carrying it decay, it is liberated, and in the free state any surplus not taken up by roots leaches away and is lost within a few months. On this account the supply in the soil can be kept up only by adding to it every year or so the quantity taken out by the trees and lost through incidental leaching.

Soil Supply Dissipated

The legumes gather more nitrogen from the air than other plants because of certain bacteria which accompany them on their roots, and without which they do not thrive. A ton of legume hay contains about 40 pounds of nitrogen. The different legumes vary a little in content of nitrogen, and in the amount carried above and below the ground. But in general it is near enough correct to count that every ton of dry plant growth of clover, beans, peas or vetch—roots, stalks, leaves and blossoms—will give you the 40 pounds of nitrogen. Since an average crop of these plants is a couple of tons or more, their annual use as cover crops will increase the supply of nitrogen against all losses without the addition of large amounts in commercial fertilizers.

Amount in Legumes

Legumes get a large part of the nitrogen they use from the air and a smaller part from the soil. Before they will succeed, the soil must contain a little nitrogen and must be loose and porous. In a soil that is harsh and devoid of practically all nitrogen the start should be secured by first using lime and then turning under rye, or some other plant that will provide organic matter, thor-

oughly loosening and fining it at the same time. Conditions then soon will be such as to permit of the successful growth of good crops of the more valuable plants.

It is the top-soil that under usual conditions of shallow tillage contains practically all the nitrogen. The subsoil contains little or none. The reason is that most of the organic matter carrying the nitrogen that is turned under is placed in the bottom of the furrow, or is distributed from this depth upward.

Under any tillage system, the bulk of the organic matter put into the soil must be merely plowed down. It cannot be mixed with the deeper soil immediately, except in the form of the roots that penetrate deeply and that carry down much nitrogen. It is not long before deeply broken soil becomes impregnated with a small amount of nitrogen as far down as it is loosened and powdered. This cannot help being of great advantage to trees, the roots of which occupy the lower soil rather than the top 7 inches. When the trees are compelled to get all their nitrogen out of the top few inches, or at most the top foot of soil, in orchards worked no deeper than the plow goes, they seldom get all the nitrogen they need because only part of their root system can get at it.

Getting Nitrogen Distributed Deeply

Too much stress cannot be placed on the value of a deep layer of loose, fine soil as a filter-bed that will catch escaping nitrogen and other plant foods. The excess water that percolates through 4 feet of fine soil particles loses much of any burden it carries, and this salvaged material is deposited deeply, where it is relatively safe from further leaching as well as convenient to roots under proper condition.

Loose Soil Prevents Leaching Loss

At Lynchburg, Va., blasting the soil for shade and ornamental trees has become a recognized practice. Notice the excellent growth of new wood on the ends of the limbs of this elm.

It should be understood that free nitrogen is not taken right out of the air and fed directly to roots. It has to go through 3 or 4 chemical changes before it reaches the stage in which roots can take it from the moisture films in the soil particles. These changes, known to agriculturists as nitrification, are important in this discussion only because they require air, capillary moisture and bacterial action.

Tillage Helps Nitrification

The process of nitrification is much hastened when soil conditions are good. *In fact, in soil that lacks air and which is either very wet or very dry, it is difficult to keep nitrogen in an available form,* no matter how much organic matter may be present. It either is liberated and escapes, or it reverts to an unavailable form. This is illustrated in muck and

peat, soils that are almost entirely composed of the remains of plants, rich in nitrogen in an insoluble form. Therefore, adequate supplies of free nitrogen are to be found only in soils that are well and deeply worked.

The methods of working the soil are unimportant, so long as they are thorough and effective enough. Deep tillage implements will do good work to a depth of 18 inches under favorable conditions. Blasting will do even better work to any required depth. The repetition of the full discussions of this matter on pages 15 and 21 is not necessary here.

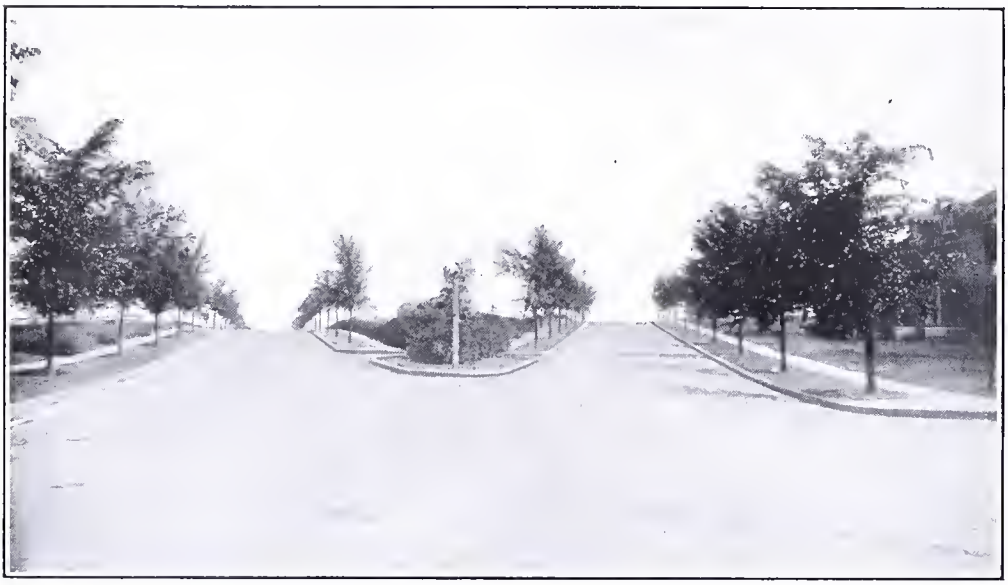
Methods of Working Soil

During years past some friends of soil blasting have claimed for it certain other advantages that never have been proved. It is unnecessary and undesirable to list them in this bulletin, for no exact data are available on which to base conclusions. Furthermore, whether or not such claims are true is of little importance, because of the overwhelming value of the direct physical tillage action of proper soil blasting, which cannot be questioned. *Soil blasting is intensive deep tillage.*

Treatment of Different Soils

Practically all clay and loam soils respond wonderfully to tillage blasting, requiring only the addition of lime, the required fertilizers and cover crops, of course, to make them produce record-breaking crops. But there are a few soils that differ in nature from clay and loam to such an extent that intensive deep tillage is of no benefit to them.

One way of making clear the proper treatment for each soil would be to describe every important soil in the country, giving its nature and suggestions for exactly the sort of tillage best suited to it. For instance, we might describe limestone soils, redshale soils, sassafras soils and so on down a long list, making clear the types of each soil. This, however, would be a cumbersome way of going about the matter.



Lynchburg, Va., where a great many ornamental trees are set in blasted ground. These trees show by the amount of new growth exhibited in the pictures that they have plenty of moisture and food.

Soils are classified by the Government and by agricultural authorities largely according to their origin, as is illustrated in the ones named above. Yet to the practical orchardist, with a practical problem in fertility and moisture supply to solve, the vital factor is first the size of the particle and second the condition of the soil with respect to amount of organic matter present in the particular land he has. Therefore, it seems that the things to talk about here are the structure, texture and condition of soils, rather than their origin.

About 10 types, or degrees of fineness of particle, usually are recognized, ranging from pure clay, through various degrees of silt and loam, to pure coarse sand. The clays have the finest particles; the sand the coarsest. As a general rule it can be said that the smaller the particle of the soil the greater the benefit it will derive from any sort of intensive tillage.

The fine particles seem to give up their natural fertility easier than the coarse ones—they respond more to proper cultivation. As the size of the particles increase, less and less plant food will be released from them under any conditions, and less and less improvement will be made by intensive tillage in the drainage, moisture storage capacity and nitrogen supply.

When the particles reach the size of SAND and especially COARSE SAND, with little or no clay or loam added, the soil has all the porosity it needs and the particles are located so as to give their greatest surface area per cubic foot of soil when the ground is packed about as hard as it ever gets. To loosen up such a soil decreases its moisture storage capacity, already low, without any other effects. Such coarse-grained soils should not be blasted.

Muck Soils Are composed of the remains of plants mixed with sediment deposited by standing water. The material remains muck instead of decomposing further and becoming loam, because of the absence of air and bacterial activity. They should first of all be drained of their excess water by proper ditching. This will leave them porous enough for best results without further loosening.

Clay Soils Vary greatly in structure and condition. Their moisture holding capacity is high, and they usually need draining. Some of them have clay and nothing but clay, compact and practically water-tight from top-soil to a depth beyond the reach of roots. Such a clay soil should be broken up and fined to a depth of about 4½ feet under ordinary circumstances, as this is about all the depth that can be kept open and porous.

While in some clay soils the layer of clay may be thin—often only 6 inches—in others it is 3 or 4 feet, or even 5 or 6 feet thick. Under the clay there is often a layer of gravel or sand. Such soils should be *broken up* clear to the bottom of the clay layer, and if the clay is thin and near the surface, the breaking should extend into the layer of earth under it, at least through a total depth of 4 feet.

Loam Soils Also vary greatly in structure and condition, but almost universally they require the same sort of deep tillage for planting trees. They should be fined and loosened to a depth of at least 4 feet. Occasionally loam should be loosened deeper, on account of need for drainage. The subsoil of long-cultivated loam generally is very much compacted. These soils usually are fairly well drained naturally, but may require special attention in this respect. Coarse sandy loams and gravelly loams seldom require deep tillage.

Hardpan, Cemented Gravel, Bound Loams and Sands And other layers of tight soil may be found in either clay or loam, and sometimes even in sandy ground. The particles of the hardpan usually are very fine. This layer of compacted and hardened material may be as thin as 3 inches or as thick as 6 feet. It should be broken entirely through in every orchard where found.

Stony Land Does not differ in tillage requirements from soil without stones. The stones seem to help in moisture storage a little, and in orchard soil are not regarded as a detriment if they are small.

How to Blast Orchard Soil

Proper preparation of ground for planting trees is little different from correct tillage of orchard soil between and under growing trees. The principles are the same and the mechanics of the actual blasting differ but little.

Soil Must be Dry

The first care in every case must be to see that the subsoil is dry. THE SOIL SHOULD BE AS DRY AS POSSIBLE—the drier the better. Unless the subsoil is so dry that it has but little plasticity the action of an explosive will not give the maximum quality and quantity of tillage results.

The reason why soil cannot be blasted with proper results when it is damp or wet is easily shown. Strike a wet clod with a spade. Instead of loosening under the pressure the clod becomes compact and makes a solid lump. Now strike a dry clod in the same way and you will crumble it. If it is very dry you will pulverize much of it into dust. Damp and wet soil becomes compact under pressure. Dry soil crumbles.

If ground is wet or quite damp when it is blasted, the effect is only to make a ball-shaped hole 2 or 4 feet underground, more or less covered with loose earth. The soil for about a foot on all sides of the immediate spot where the charge of explosive was located will be compressed instead of shattered. The sides of the hole, so formed, and the bottom, will be tightly packed. A few cracks may extend into surrounding soil, but 95% of the effect of the blast will be confined to a sphere 2 or 3 feet in diameter, with positive packing instead of loosening. THIS IS NOT GOOD SOIL BLASTING. It will not give the benefits that have been described in previous chapters of this bulletin. Except in isolated instances it will disappoint anyone who tries it with the expectation of good results.

These two pictures are included to show two things. One: how *not* to blast tree beds; never permit the blast to blow dirt out, as these blasts are doing. Keep the amount of the explosive reduced to the point where the surface of the ground will be only heaved. The other: how a blast crumbles dry soil; the ground is drier in the left-hand picture, hence the soil crumbles to dust. You can see the stones among this fine soil, in the air. In the right-hand picture the soil is damper, and does not powder as well. See pages 3, 4 and 5 for other pictures.

The conflicting results from "soil blasting" which have been noted in various orchard experiments and tests, and about which much discussion has been aroused, have been due largely to variation in the condition of the soil at the time of blasting. As might be expected with a new process, the methods of practice have not become standardized. There are as surely right ways and wrong ways of blasting as of plowing. Much of the blasting of the past few years has been done in ways that in the light of present knowledge could be expected to give but little if any benefit.

When the soil is dry at the time of blasting, the effects of the explosion reach out many times further than when it is damp, and the breaking and fining action of the gases is much more thorough and complete. If any cavities are formed underground they can be easily filled by running a shovel into the bed of the blast. In actual planting, the loosened dirt should be shoveled out.

When to Blast

In respect to the time or date of blasting, good results are derived when the work is done just before the trees are planted—provided the ground is dry. It is rather difficult, however, to bring the two operations together while doing both justice.

Trees usually should be planted when the ground is damp or wet. You can plant trees in dry ground successfully, however, though you cannot blast wet ground successfully under any circumstances. If you plant, in dry ground use two or three gallons of water about each tree.

Spring usually is the best season to plant in the North, but blasting ground in the spring before too late to plant trees is a matter of luck. Proper conditions occur at that season only once in several years. Sometimes you can do it; more often you cannot. Fall planting usually is not advisable in the North, though in the South it often is to be preferred. In fact, in the South, planting can be done successfully without interruption from the time the leaves drop in autumn till the buds open in the spring.

All things considered, blasting of orchard soil usually can be done to the best advantage in July, August or September, after a prolonged rainless period of weather. Sometimes the ground is dry enough in May or June; once in a while it is dry enough in October or later in the fall.

Blasting soil in the summer or fall for planting the following spring is entirely successful. The plan has many advantages. The action of sun, air, frost, water and other agencies during the winter on the loosened soil results in much increase in its fertility and cavities made by the blast become filled. A cover crop should be growing during the fall months in the blasted ground, whether the tree is planted or not.

When planting must be done in the spring and the soil blasting has not been done the previous fall, it is all right to blast if the subsoil is dry, and will conform with the tests given on page 32, but if it is wet, the better plan is to plant the trees without blasting, then to blast the soil about them during the following summer. This can be done with satisfaction. The details are explained on page 38.

Depth for Charges

The proper position of the charge in the soil depends on the nature of the soil. It should be deep enough to break the soil down 4 feet, and in many cases the effect of the blasting should extend deeper, even as deep as 6 or 8 feet, but such depths of blasting are advised only for a few kinds of trees. Individual comments on certain soil conditions are necessary to make clear the proper depth for charges.

It must be understood that intelligent placing of charges depends altogether

on examination of the soil with an auger or by digging. Without the tests it is guesswork.

The proper depth of the charge depends on the thickness of the hardpan layer. In any case the soil should be broken to a depth of 4 feet.

Hardpan Usually, the layer of hardpan is so placed that the charge should be located about ⅔ of the way down through it.

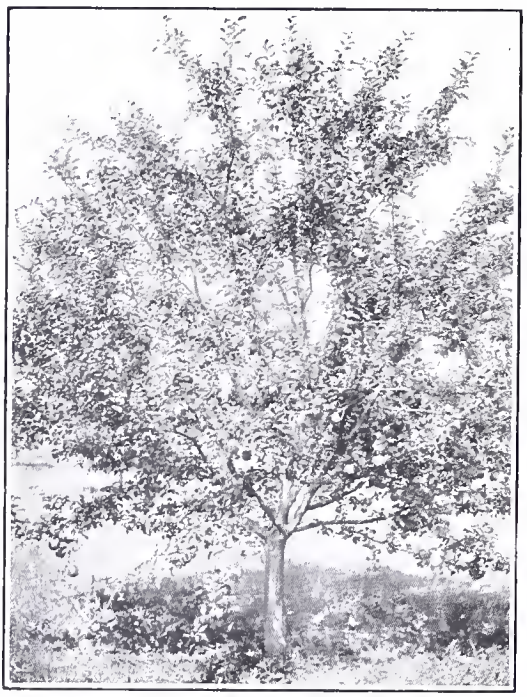
In case the layer of hardpan is thicker than 4 or 5 feet, it is almost impossible to break it entirely through at a reasonable cost. The charges should be placed in such soil about 4 feet deep with the object of loosening and fining a section of the soil 4 feet deep, leaving the underlying hardpan intact. But it is best to break the hardpan entirely through to a softer, more open layer of earth underneath when practicable.

When there is loose or open ground below a relatively high and thin layer of hardpan, the charges of explosive should not be placed so near the bottom of the layer that the force of the explosion will escape into the loose ground below and only break the hardpan into large chunks instead of crumbling it. The remedy is to locate the charge higher in the hardpan, but do not place the charge so high in the layer that the blast will break through to the surface of the ground without shattering the hardpan to softer ground below.

CEMENTED GRAVEL and other tight, bound soils usually lie in layers similar to hardpan, and should be blasted in a similar manner.

Clay soils may be composed of solid clay or the clay may lie in thin or thick layers. Also the clay may be near the surface or may be covered with 1 or more feet of loam or sand. When this occurs, the clay, if less than 4 or 5 feet thick, should be broken through to more open soil beneath. The placing of the charges to do this is precisely the same as in hardpan, as described in the previous paragraph. Where a thin water-tight layer of clay occurs 4 or 5 feet below the surface, the charges should be placed right down on the clay, in order to break it through.

Clay



A typical tree in the orchard of H. M. Magee, Waynesboro, Va. Planted in 1901 in a blasted bed, it began fruiting in 1907, yielding 1½ bushels when 6 years old. The following years its yield was 2¾, 3, 10½, 12, 14 and 13¾, until 1913. The picture shows the condition of the tree in respect to growth.

Loam soils, of all kinds, offer simple problems. They may or may not have a plowsole. The subsoil may be loose or very compact. In any case the charge should be about 3 feet deep. Loams containing a large amount of fine earthy sediment are benefited by loosening and fining, but the charges should be placed well to the surface—say within 2 or 2½ feet in depth. When the subsoil is heavy, as when of distinctly clay nature, the charges should be placed a full 4 feet deep.

Loam Soils

Shale and Slate

Shale and slate surface soils, whether of clay, sand or loam type, often are underlaid with rock. This rock may be brittle and soft, and may be broken up to give more root space. Place charges in the rock as deep as 18 inches below the last of the loose soil. The charges should be heavier than for blasting hardpan.

Size of Charges

The amount of explosive to use in each charge must be governed by the depth at which the charges are placed and the hardness of the soil. A strongly cemented hardpan, for instance, will require almost double the charge that is proper for a relatively light soil. Clay, when heavy, requires almost as much explosive to the charge as hardpan, though it shatters under much less force when it verges close on having a loamy nature.

Fortunately, no doubt is necessary about the correct size of the charge for any particular soil, as there is an unfailing rule which determines the correct amount of explosive to use. *After you have made sure of the proper depth for the charge by boring or digging into the soil and locating and identifying the various layers composing it, use just enough explosive at this depth to break the ground to the surface without blowing out a crater.* The surface of the ground should be heaved and lifted, especially showing a bulge over the charges, but very little of the ground should rise into the air at the time of the blast. When the ground is quite dry the explosion will create considerable dust, which will float above the surface.

The usual charge for blasting tree beds will be about half a stick of explosive (1/4 pound) when the charge is located 3 to 3½ feet deep. At 4 feet, ¾ of a stick likely will be required. At 2½ feet deep the charge likely will be only ¼ stick. These figures should be the basis for making the first test shots, but after the tests *the size* of the charge should be regulated entirely by the *results noted*, as described above.

It must be remembered that some soils require considerably heavier charges than the above stated ones. It is no rarity to find a hardpan condition requiring 1-stick charges placed at a depth of 4 to 4½ feet, and certain hardpan and clay conditions require the placing of 2-stick or even heavier charges at depths of 6 feet.

In general small charges are more desirable than large ones for tillage blasting or orchards. The usual method of blasting ground for trees is to place one charge where each tree is to stand.

The trend of practice among those who have studied the matter and have had much experience is to use several light charges placed

A soil auger often can be used to good advantage in making holes for subsoil charges, particularly in heavy soil. Holes started to a depth of one or two feet with a bar can be finished easily with an auger.

not very far apart rather than one large charge, to do the same work in preparing the ground for a tree, or in tilling the ground about one. This is particularly applicable in deep clay and hardpan.

Number of Charges per Tree

An explosion is necessarily more violent close to the charge. Its fining and crumbling effect diminishes as the distance from the charge increases, hence 3 small charges placed at the corners of a triangle, or 5 small charges distributed over an area about the point where a tree is to be set, will produce a condition superior to one charge located in the center of the area.

Spacing Charges

The distance between charges is of course governed by the spacing of the trees when only one charge is used in each tree bed. *When more than one is to be used for each tree and when the ground between the trees is to be blasted, the charges should be so spaced as to break up all the ground.*

When 3 or 5 shots or more are used for each tree or tree bed, the spacing between charges should be 6 to 10 feet. In case of blasting the ground between trees the charges can be spaced 6, 10 and sometimes even 18 feet apart. The only way to determine exactly how far it is best to space them is to dig or probe into the ground after 3 or 4 trial shots. Note how far the crumbling and pulverizing effect of the blasts extend and space the charges accordingly.

In ordinary loam the average properly balanced blast will break as far as 8 or 9 feet away, though the ground at the edges of this circle will not be well shattered. When the orchard is large each charge should be relied on for its extreme range, but in small orchards, particularly in home fruit gardens, where economy in the blasting can be a secondary consideration, the soils should be blasted with charges placed from 6 to 10 feet apart.

A Mammoth Black Twig apple tree in the Rose Cliff Orchards, Waynesboro, Va., growing in blasted ground. The tree has set a heavy crop of fruit and at the same time made a good growth—see the twig ends. To do this the tree must have abundant moisture and food available during the growing season.

Making Holes

The holes should be made straight down. Soil that is dry enough to be blasted offers considerable resistance to a bar or soil auger. Ordinarily the subsoil bar will make the hole quicker and with less work. In stony land the bar must be used. Sometimes a good practice is to drive the bar down a foot or a foot and a half, or as far as it will go under a few strokes of the sledge, then use the auger for the rest of the depth. When drilling dry ground with the bar, the hole should be filled with water.

The holes should be loaded in the ordinary way, as explained on pages 49 to 51. Put the charge of explosive in the bottom of the hole, push in about 5

Loading Charges

inches of dirt, but do not pack or tamp it, then insert the tamping stick and as you push in more dirt work the tamping rod up and down and close the hole up tight to the surface, being careful not to kink the fuse or the electric detonator wires.

Firing Charges

The charges can be exploded with cap and fuse or with a blasting machine and electric blasting cap. When the charges are close enough together to make the breaking overlap at the time of the explosions, it may be of advantage to fire them simultaneously, owing to the somewhat greater execution developed. This calls for electric firing. When the charges are spaced so far apart that they will not break all the intervening ground, simultaneous firing is of no advantage. Electric firing involves more trouble than fuse firing, and is considerably more expensive.

Kind and Grade of Explosive

The explosive to use for blasting orchard soil invariably should be a comparatively slow acting one. Since the ground always is dry, no waterproof qualities are required. Use 20% or lower strength ammonia explosives.

Time and Cost

Making the holes in the ground is the big labor item. Loading and firing labor is small. One man should make and load 50 to 100 or more holes per day in loam or silt soils in good condition. In certain hardpan soils the same man might make less than 50 holes a day.

The cost of both labor and explosives vary so much from time to time and from place to place that to name a definite figure of cost for blasting orchard soil is risky. The cost, however, ought not to exceed ten cents per shot, on a basis of half a stick per charge.

Computation of the average cost per acre is inaccurate, because no two orchards will demand the same treatment. By figuring the cost per tree, or per charge, and using the following table to determine the number of trees or charges in an acre, you can arrive at about what the acre cost in your orchard will be. Nearly every fruit grower knows how many trees he has—knows this when he does not know the exact acreage—and the cost for the whole orchard easily can be figured on the tree basis.

	Number of holes to an acre, square method	At various spacings, triangular method
40 feet apart	27	31
35 " "	35	40
30 " "	50	55
25 " "	70	80
20 " "	110	125
18 " "	135	155
15 " "	195	225
12 " "	305	350
10 " "	435	505
8 " "	680	675
6 " "	1,210	1,600

It does not cost less to blast tree beds than it does to dig the holes, though the blasting may save some labor. The soil can be shoveled out of a blasted tree bed quickly, but digging without blasting is a slow job. To make the holes for the charges, to load, to fire and to shovel out the dirt, takes about as much time as to dig average holes.

Blasting Soil in Standing Orchards

To blast the soil in orchards already planted, even when the trees have reached full size, is entirely practicable. In fact, this is one of the recognized methods of renovating and improving old orchards.

Precisely the same principles apply to this blasting as to blasting the soil in preparation for planting trees. The only difference is that imposed by the necessity for avoiding the bruising or tearing of roots. The ground must be dry and the charges must be placed at the depth demanded by the nature and condition of the soil.

Ordinarily the best way of going about the work is to put in the ground very light charges (¼ to ½ a stick of explosive) at the proper depth about the trees under the end of the limbs. Most of the feeding roots likely end nearly underneath that point. Some of the roots within 12 to 15 inches of the charges will be broken by the explosions, but beyond this range they will not be damaged much or at all.

Size and Depth of Charges

Trees that have been planted only three or four years will have limb spreads too small to come under this rule. To blast the soil about such trees, keep the charges away about 4 to 6 feet from the trunks. Each tree-bed should be blasted with at least three charges.

About large trees the charges should be spaced 8 to 15 feet apart, in order to break *all* the soil. Possibly the blaster should be satisfied with a little less surface breaking in a standing orchard than an open field or a garden. The correct growing-tree blast will have little visible surface effect. Nearly all of its execution will be confined in the ground 2 or 4 feet underground, or deeper.

It is doubly a mistake to use heavy charges about growing trees. The local effect is too severe. Charges of a full stick will break and bruise a good many roots. But the small charges recommended, will not, as a usual thing,

Few well-informed orchardists attempt to start a commercial fruit plantation without making intercrops 'pay some or all of the expenses of caring for the trees. To do this requires that the land be productive of the crops planted between the trees, and that the trees themselves grow fast and bear soon. Intensive deep tillage helps wonderfully in securing both results.

break roots farther than a few inches. Beyond 10 or 12 inches the ground will be loosened and fined for several feet, without any particular hurt to the roots.

The ground beyond the ends of the limbs of the trees always should receive attention. If you thoroughly and deeply work this soil, the new growth of roots will run out to it within a year or two, accomplishing what you are after without much pruning of the root system. The trees in the average orchard are spaced only far enough apart to permit a maximum development of their root systems, hence you should skip none of the ground between.

Blast Soil Between Trees

When blasting the soil under and about large trees, it often is a good plan to blast on two sides of each tree one summer, and on the remaining two sides the following season.

In very poor soils the plan of blasting out deep craters between the trees sometimes is advisable. This serves the double purpose of permitting greater root penetration, improving tilth, and giving a chance to establish a reservoir of plant food and moisture by filling the hole up with manure, commercial fertilizer and mellow top soil, mixed together. The roots quickly will find such a feeding ground. Be sure to include a big proportion of vegetable matter—leaves, grass or straw—with the material used to fill the craters.

Blasting Out Craters

The season when tree blasting had better be done is when the ground is dry. The only possible objection to August or September blasting would be that it might force a fall growth. To blasting non-bearing trees in July there is no objection, nor can there be any to blasting after the first frosts have come in the fall and the trees have ripened their new wood. For bearing trees, the blasting should be done as soon as possible after the first frost.

When to Blast

Good Orchard Soil Management

Practical orchardists will ask how correct blasting of soil should be fitted into the regular tillage schedule. The following suggestions do not make a comprehensive outline of the orchard tillage subject, but are intended as a series of more or less connected hints on methods of cultivation.

Trees of any age grow faster when well watered and well fed than when either water or food is restricted. The blasting of soil is designed to increase the supply of both, hence should result in bigger trees at any age. Other things equal, big trees certainly will bear more fruit than smaller trees. They have more bearing wood.

Whether or not the trees bear sooner in blasted ground than otherwise is a matter of condition of the trees when they reach 4 or 5 years of age. If they are growing very rapidly they will not bear well. If they are not supplied with proper nourishment, they will not bear. The trees that bear young are those which have grown vigorously during the first two or three seasons, and then receive some sort of check, but which have good food and water conditions. Lack of moisture in late June or early July may throw the growth of a young tree into making fruit buds. Lack of plant food, summer pruning or insect attacks may do the same. In any case, you cannot get early bearing from trees that are not vigorous, hence to put the soil in condition to produce vigorous trees is a step toward early bearing.

The same soil condition is a preventive of insect and fungus damage to trees, in that vigorous trees will not be overcome by an attack of scale, cedar rust or other orchard enemies as easily as or quickly as one that is growing slowly.

In the case of bearing orchards, the man who blasts the soil has every reason to expect larger fruit than the man who does not. It gives the trees a greater supply of moisture to put into the fruit. The growth, health, and vigor of these trees cannot but be improved by the additional supply of plant food made available, and instead of declining and deteriorating, the trees should become stronger and better each year, unless they have already reached a very advanced age.

The need of intensive deep tillage is greatest when heavy intercropping is practiced in the orchard, and it is under such conditions that soil blasting shows its most pronounced results. This is a western scene, but so far as soil and weather conditions are concerned, it might be anywhere in the country that fruit is grown commercially.

If possible, plan for your blasting some months ahead by sowing a heavy-rooted cover crop in the spring. This is not essential, but it is desirable. Do the blasting in the summer or fall. In July or August, if the spring cover crop has not been plowed down before, turn it down and sow another which should occupy the ground until the following spring.

The use of so many cover crops is advisable because organic matter must be supplied in plenty to the soil if the correct soil processes are to be continued, and a proper condition of granulation is to be brought about and maintained. Blasting or other forms of deep tillage and cover crops go together. Blasting is not half so beneficial without the heavy growth of roots as with them.

In the orchard where the clean cultivation system is practiced, plow as early as possible the next spring after blasting, and keep the ground harrowed every ten days or after every rain until late in June or early in July. Then sow a cover crop again. The surface mulch of loose soil conserves the moisture while the trees need it. The oncoming cover crop takes up the moisture and hastens ripening of soft growth of the trees at the proper time.

The orchard soil should be limed liberally. The best form of lime to use in orchards is the ground raw stone. It should be applied at the rate of 2 tons an acre every 3 or 4 years. The first application should be made during the summer the blasting is done, though it may be given in the spring before, after the ground is plowed for the cover crop.

The use of cover crops is closely associated with the length of time the effects of blasting will last. The deep tillage opens the soil, let us say, to a depth of 4 feet. Unless there is something to keep the particles apart, each winter and each period of wet weather will see more of them floated together into the former compact conditions, but when cover crops are sown the roots go down to the bottom of the layer of loosened ground, and act as lightening to the soil, making it more and more loamy. When practicable, be particularly careful to get a good heavy stand of the cover crop plants close up to the trunks and all about under the limbs of the trees.

If the blasted soil is supplied as it should be with vegetable matter in the form of roots and cover crops plowed under every year, there is no reason why the soil should become compact again for 15 or 20 years. Mere mechanical loosening of the soil, whether with plows or explosives, may not keep it loose nearly so long. Probably under average conditions, it will be well to repeat the blasting every 6 to 10 years.

The kind of cover crop is important only in two respects. You must grow clovers, peas, beans or vetch to get nitrogen. You must grow annual, or bi-annual plants instead of perennials, in order to have dead and decaying roots in the soil rather than living, growing ones. (Weeds, rye, oats, sorghum, millet and many other plants are excellent sources of organic matter).

Any sort of plant will gather and later liberate some locked-up plant food. On this account plants can be called "miners" and "refiners" of slowly soluble plant foods. The fact that they do this is another reason why it is important to have abundant quantities of roots growing deep into the soil.

In grass mulched orchards it is well to plow up the sod every 4 or 5 years in order to force the roots of the trees down from the surface. Otherwise, they will tend to gather just under the grass. The plowing should be done in the fall following the blasting, or the next summer. Soil blasting is especially valuable and beneficial in a grass mulch system of culture.

The fertilizing of orchards under a proper system of intensive deep tillage is a very simple matter. If you grow legumes as cover crops, you will get much nitrogen from the air. Usually, some additional phosphorus, and if available, potash should be supplied. If the trees indicate a lack of nitrogen, by showing yellow leaves and by other signs well known to most orchardists, use a little nitrate of soda, cotton seed meal, or other heavy nitrogen carrier. Lime, of course, is needed, but lime should not be considered as a fertilizer. It is largely a corrective of sourness and a mellowing agent.

Planting Trees in Blasted Beds

Shovel out about a bushel of dirt at the point where the tree is to stand. Then with the shovel probe and pry down in the bottom of the hole to see if there is any cavity or pot hole left by the blast. If there is a cavity, pack it full. If the shovel goes in too easily, work it about to compact the ground. Better get in the hole with your feet and tramp the ground a little. If you do not settle the loosened ground in this way, the tree will settle considerably after planting. In case your trees do settle, it is not the fault of the blasting, but of careless planting. The bottom of the hole should be 6 inches lower than is proper for the roots.

Stand the tree in place 6 inches too deep and sprinkle in some fine, mellow soil. Work this among the roots. You have three means of doing it—tamping among the roots with a stick, working the soil in with your fingers, and shaking the tree up and down. The latter is one of the best means, and should never be neglected. In the process of alternate lifting and pushing down, gradually raise the tree the 6 inches and settle it firmly on a well packed layer of earth at the proper depth, which is determined by the dark line about the trunk, an inch below the surface of the ground.

As the dirt fills up about the roots, pack it very hard. Get in with your feet and tramp it till you think the roots will not have breathing space. You cannot well get it too tight. Sometimes a heavy wooden maul or a broad-faced iron sledge is handy for packing the ground about the roots.

The top 3 inches of ground should not be packed. In fact, it is well to go over the planting four days to a week after it is done, with a garden rake, and loosen any crust that has been formed on the ground about the trees by the drying of rain or dew-soaked surface soil. This will prevent waste of soil moisture. At the same time glance along the rows to make sure of the final line-up of the trees.

When the blasting is done in the summer or fall, and the trees are to be planted the following spring, some lime may be sprinkled over the ground with good effect. It is even better to shovel out the loose earth and sprinkle some lime in the bottom of the holes. The lime will help to make the soil more mellow.

Orchard trees should be pruned soon after planting. If they are left with high, heavy tops the wind will work the roots loose in their new beds before they have had a chance to take hold. By cutting back the limbs properly the wind is given less chance at the trunks.

Steel bar for making holes.

Soil auger—note long point.

Preparing Charges of Explosives for Firing

A charge of explosives for the purposes of these directions is considered to be all the explosives needed for a single hole with cap and fuse or electric blasting cap properly inserted in the stick of dynamite or powder (see pages 44 to 45) and tamped in the hole, ready to fire. The preparation of charges is practically the same for all sorts of farm blasting. The slight variations advisable to suit different kinds of work are not enough to call for separate treatment, since the principles are all the same.

What a Charge is

All who use and buy explosives should read the next chapter, beginning on page 53, on the nature and actions of explosives. It is only the man who understands all the facts mentioned there who will be able to load and blast with greatest ease, speed and results.

Scope of This Chapter

It is important for everyone who blasts to understand why he does things, as well as how to do them. For that reason the following discussion of the preparation of charges is made full and complete, with due attention to all the important factors involved. Details of any particular part of the operation can be found quickly by referring to the heading desired, as given in the index.

Readers who may not desire a full discussion are referred to the following brief outline of the process.

Be careful that explosives, cap and fuse are in perfect condition. Cut a length of fuse sufficient for the hole to be loaded, making the cut clean, without dragging ends, at a slight slant of, say, 30 to 45 degrees from right angle.

Pick a cap from the little tin cap box, carefully, with your fingers, and slide it gently on the end of the fuse. With a proper cap crimper fasten the cap securely to the fuse, making the crimp close to the open end of cap. Avoid twisting or punching the end of fuse against the bottom of cap as well as drawing it away from the bottom. For wet work waterproof the joint of cap and fuse with tallow, soap or other material. Do not use thin grease or oil.

Next punch a hole at a long slant in the side of the stick to be primed. Better use a wooden punch for the purpose. The handle of the cap crimper may be used.

Insert the cap in the hole made as described, tie the fuse in place, and, for wet work, waterproof all openings in the stick. You then are ready to load.

Provide space enough in the hole at the proper point to hold the required amount of explosives in a bulk that is not too long. Be sure before you start to press in the sticks to the bottom of the hole (see pages 36, 49) that there is enough clearance to permit their easy and certain entrance. Tamp fully and firmly up to the top of the hole.

The charge is now ready to fire, which may be done by pressing the burning or flaring head of a freshly scratched match against the powder in the split end of the fuse.

Carrying Explosives and Supplies

The place to keep the explosives is in the magazine or storage place, and not with you in the field. Carry with you in warm weather only enough for the job or the day, or in cold weather only as much as can be kept warm and in condition for firing until you are through loading. Keep explosives separate from caps.

Protection of Explosives

A good way to carry the caps, fuse and small tools is in a basket. Put a piece of blanket in the bottom, to keep

out dampness when the basket is on the ground. Some blasters use an explosives box for the purpose, putting a wood handle or double wire bale on it. The tight wood box probably is a little better than the basket because it affords somewhat more complete protection to the contents.

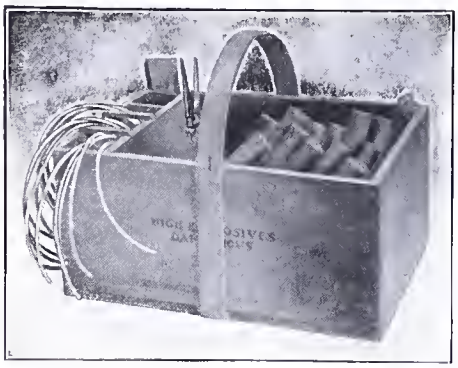
Whatever the method of carrying the explosives, it should be well protected. This consists in keeping the hot sun off it, keeping rain and fog off it, keeping it away from dampness of the ground, and keeping it safe from meddlesome people and animals.

Many blasters prepare charges before going to the field, but it is better practice to carry along the tools and materials, and to put them together or make the primers on the spot after all the holes are made in the ground or rock, and when everything is ready for the firing except to put the explosive in place.

These remarks are given as reminders. Full discussion of proper handling and storing of explosives can be found on pages 68 to 70 respectively.

Tools and Materials Required

The first step in preparation of charges is to assemble the following: as many sticks of explosive (or parts of stick, if charges are to be less than full sticks) as there are holes to be primed; an equal number of caps; a sufficient quantity of fuse; some string; a wood punch with an end the size of a cap for about 3 inches; a pair of cap crimpers; a pocket knife. If the holes are very damp or full of water you also will need some tallow or other waterproofing material. In certain cases a sharp hatchet or axe and a block of wood will be worth having. The purpose and use of these items will be made clear later.



A handy box for carrying supplies to field.

Putting Caps and Fuse Together (Making Primers)

Fuse is described as to sizes and properties on page 67 and caps on pages 66 to 67. Readers who are not familiar with them should turn to those pages at this point. Unroll the fuse and cut off a length that will be enough, since fuse burns about 2 feet in a minute (there are variations—see page 68).

The Fuse

Three feet will give you 1½ minutes or a sufficient time to get beyond danger under ordinary conditions. The fuse, of course, must be long enough to reach out of the mouth of the hole when the charge is in place. Measure the depth of the hole before you cut the fuse.

Warm cold fuse before attempting to bend it. It may be taken into any warm room for the purpose but should be subjected to no heat greater than 110 degrees. If for any reason you have doubts about the condition of your fuse, cut off a foot or more and try it without any cap or explosive. If it will burn properly it is all right.

Be sure to get fresh ends both for the match and to put into the cap. If fuse has been cut for some time into lengths, it is well to cut off short pieces from the old ends in order to bring fresh powder right to the tips.

Cut the fuse off at a very slight angle or bevel—say 30 to 45 degrees, as shown in the diagram. This slant is for the purpose of giving a little space between the actual end of the powder and the explosive material in the bottom of the cap, to enable the spark to spit into material.

Cutting the Fuse

The only way to regulate the space is to cut the fuse as directed and let the long tip rest gently against the bottom of the cap. The spark has a better chance to ignite the explosive material in the cap when it spits from the end of the fuse than when it merely burns up to the end without any space to spit into.

The end of the fuse where cut off should be clean and free from dragging ends and threads. If it is not cut off clean, part of the covering may double over the end of the fuse in the cap and keep the spark away from the explosive, causing a misfire. Be careful to keep both ends of fuse off damp ground and out of puddles of water.

If the fuse has been mashed, or is too thick to go into the cap easily, do not peel off any of the covering. Reduce the diameter by squeezing it with the cap crimpers or by rolling it on a smooth surface under a knife blade or other smooth implement. Sometimes you can reduce it by rolling it between the thumb and finger.

The very best way to cut fuse is on a block of wood with a sharp knife. The blade can be pressed right through the fuse and will make a clean cut. Another good tool is a sharp axe, to be used on a block of wood. The method of cutting is of small importance, just so the actual cut is made smooth and even enough. If you do use other tools, have a knife with you to trim up ends that are not true. Be careful to avoid twisting, pinching or otherwise knocking the freshly cut end of the fuse about, for you may shake out the powder back far enough to cause a misfire. The powder should come out flush with end.

To get one cap out of the tin box in which they came, tilt the box up on edge till some of the caps slide forward, and then pick the cap up with your fingers. Don't attempt, on penalty of losing a hand, to take a cap out of a box by running a nail or a little stick or the fuse into it in the box. Be careful you do not drop a cap to the ground or floor.

Turn the cap upside down, to make sure there is no dirt in it, and gently slide it on the fuse till the end of the fuse just touches the bottom of the cap. Do not ram, press or twist the end against the bottom.

The Cap

Hold the fuse with capped end up, to keep the cap from sliding off, and crimp the cap fast. This you do with the special plier-like tool called a cap crimper. The "crimp" is made by pinching the open end of the cap tight to the fuse. It should be made within the last quarter inch of the open end of the cap. Never make it toward the closed end because you might disturb the explosive material in the bottom of the cap and cause it to explode.

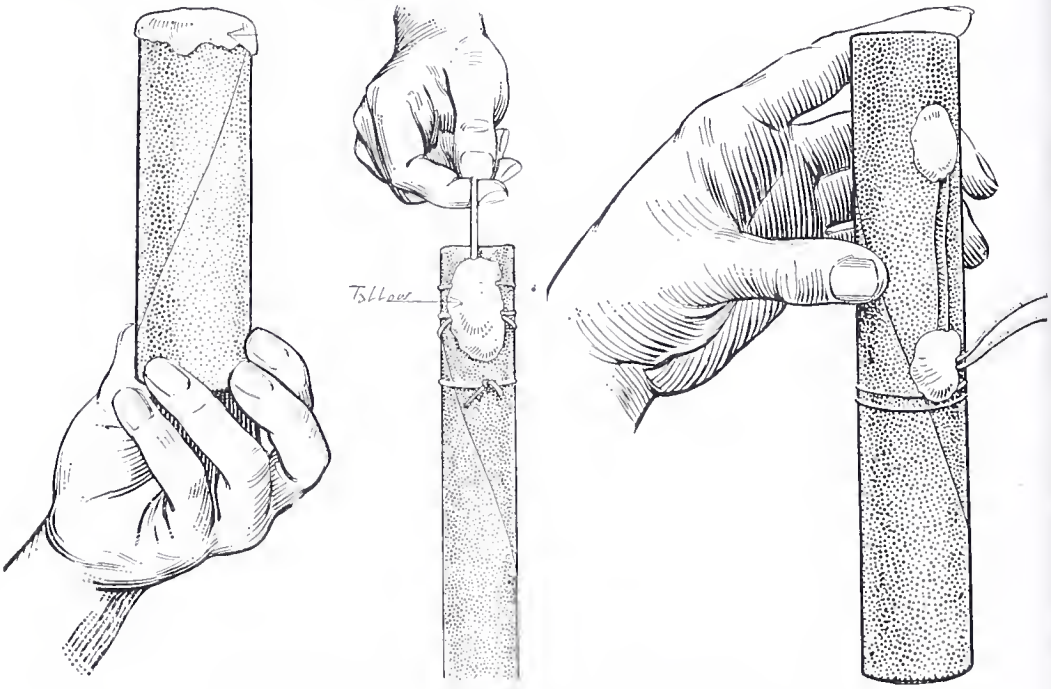
Crimping

"Crimp" or fasten caps to fuse with a regular crimping tool. This tool does the job far better than it can be done in any other way.

Cap crimpers are supplied by

all makers of explosives. Order one or more when you buy your explosive. It is well to have an extra one about to use in case you lose one on extensive jobs.

This fastening of the fuse to the cap is one of the points in blasting where a great deal of abuse occurs. Blasters think they can take a chance with danger or with misfires, and attempt to crimp the caps some other way. Except in extreme emergency don't try to crimp a cap with anything except a regular crimping tool; but there are times when one may not have a crimper nor be in a position to wait till one can be purchased. There is a way out of this difficulty —which is to secure a makeshift crimp with something else than a crimper. It is possible to use a pair of pliers, or a small pair of pincers, and accomplish something that may hold the cap on the fuse. The best makeshift crimp is to take a fold of the cap up at one side of the mouth with a pair of close fitting, square-nosed pliers. Be careful while doing this that you do not grind the end of fuse against the bottom of cap, or pull the end back from the bottom. If the fuse should pull away from the bottom of cap a quarter inch, a misfire likely would result.



Waterproofed (tallowed) sticks ready for loading in wet holes.

Waterproofing

When the charge is to be placed in a dry hole, waterproofing is not needed, but in a wet hole the connections between fuse and cap must be made water-tight with tallow or soap. Do not use grease, because it may unite with the tar in the composition of the fuse cover and soften it, when the powder train will be ruined. Water in the cap will surely make it worthless.

Inserting Caps in Explosive

The best location for a cap in a stick of explosive for farm blasting is in a hole in the side, about an inch and a half from one end. The best position for the cap at this point is at a slant that takes it in from the side toward the center, but as near longways, or parallel with the sides of the stick, as possible.

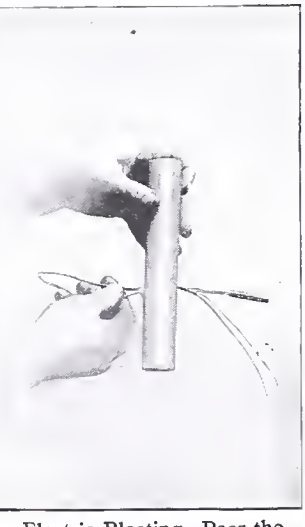
In cutting fuse from roll use sharp knife.

Taking one cap carefully from box.

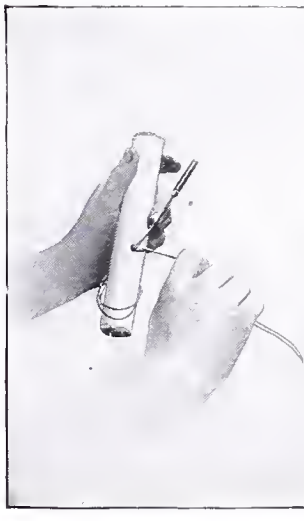
Inserting fresh end of fuse in cap.

Crimping cap with the cap crimper.

Fuse tied firmly to stick with string.



Electric Blasting—Pass the doubled fuze wires through a hole in stick of powder.



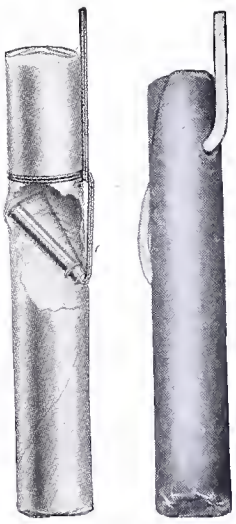
Loop the doubled end of fuze wires over end of stick.

Pull loop tight, bend wires at cap, punch slanting hole in stick high up and round to side a little.

Insert cap in slanting hole to bend of wires, take up slack in wires. (Waterproof holes if ground is wet.)

Position of Cap in Stick

In other words, when making the hole for the cap in the explosive, make it with as long a slant down toward the other end of the stick as possible. There are reasons for this connected with superior or inferior detonation.



Bad priming.

Another style of priming much used is to set the cap in a hole made in the end of the stick of explosive, and then to tie the paper about the fuse or wires. This is good so long as it is not damaged, but experience shows that the tamping stick often bends the fuse over sharply when the primed stick is pressed into the hole and sometimes even interferes with the cap itself. With side priming there is a cushion of the soft explosive between the end of the stick and cap. End priming always is good provided sufficient care is taken in loading to prevent disturbing or displacing the fuse or cap with tamping rod.

When all the explosive is removed from its stick wrappings, the cap must be inserted in the loose explosive. This should be done by making a hole, as in a stick. But it seldom pays to take all the explosive out of stick wrappings. Nearly always you can leave a half stick of explosive intact for the cap.

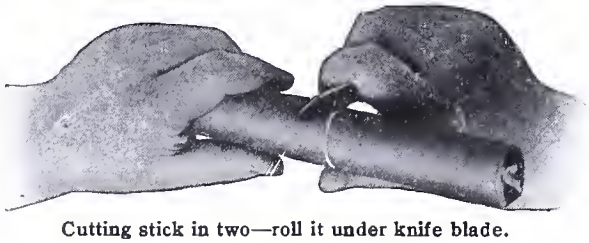
A good crimp.

Making Hole in Explosive

To make the hole for the cap use the handle of the cap crimper or a wooden punch just a little larger than the cap. The hole should be large enough to let the cap in without much pressing, but should leave no air space about the cap. The depth of the hole also is important. It should be just enough so that the entire cap can be buried in the explosive, but not any deeper. If it is deeper, the cap may be forced on down to the bottom, which will leave some of the fuse in contact with the explosive (may cause burning instead of exploding of powder), or the cap may be seated just inside the wrapping, leaving an air space at the inside end or bottom of the hole, which may lower the effectiveness of the explosive.

Fastening Fuse to Explosive

When the cap is seated in its hole in the side of the stick, the fuse will extend up along the stick past the near end. It must be tied in this position, so securely that the fuse and the cap will not be pulled back in handling or by rubbing against the side of the hole when the stick is pressed down. The best way to secure it is to wrap a strong string several times below the point where the cap is inserted, then give two or three wraps about the fuse, and pull tight and tie; or take two loops about the fuse and then several wraps about the stick.



Cutting stick in two—roll it under knife blade.

When the foregoing directions have been complied with you have a stick of explosive primed with a cap and fuse. It is ready to put in the hole in the rock or ground.

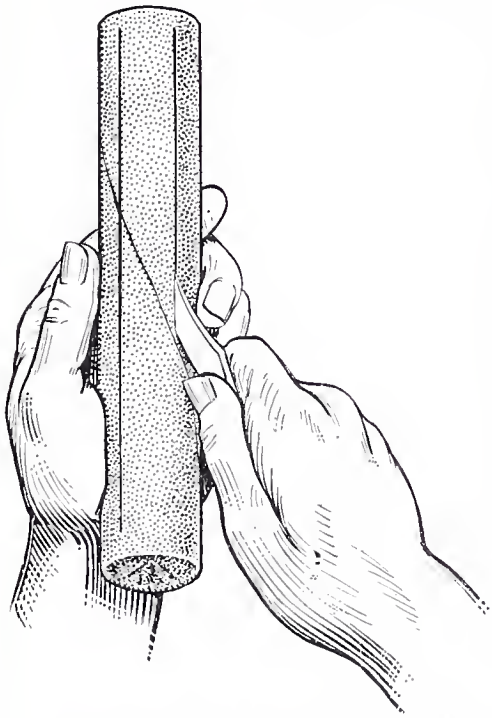
Loading Charges in Holes

You will need a tamping stick. This must be of wood, and had better be about the size of a stick of explosive, which usually will be 1¼ inches in diameter, except in case of blockhole blasting of boulders, when a smaller stick sometimes is needed to go in small drill holes. Never use a metal rod for tamping. Make sure that the hole is ready. It must be big enough to allow sticks of explosive to slide down easily (except in the case of small holes drilled in rock, when the explosive all must be taken out of the stick wrappings and crumbled and pressed into the hole). Loose stones, sharp stones and roots that obstruct the hole should be removed with a bar or spoon scraper. This work must be completed before starting to load. If obstructions fall into the hole, after some of the explosive is in place, don't try to remove it by force. Make another hole at a safe distance from the first, put in another charge and fire it.

Tamping rod

Measure the hole with your tamping stick and judge if there is space for the required charge at the right point. Nearly always a charge of explosives should be as much on a pile as possible. If one or 2 sticks are all the explosive required, it usually will not hurt to put them end to end. But if 3 or more sticks are required, to put them end to end makes the charge too long, and places the force of the blast elsewhere than where it should be.

The tamping rod should be of wood.



Slitting the paper wrapping of stick to let it swell to fill dry hole.

When your judgment tells you that the charge should be in a more or less round bulk, enlarge the hole at the point where the charge should be made. Sometimes this can be done by scraping it out at the bottom with a toe-bar or spoon-bar. Again, if much enlarging is required, it is well to use a small amount of explosive to secure it. This is called springing. To do this prime about a quarter of a stick as usual, and push it to the bottom of the hole. Use no tamping. After it is fired wait till the hole cools, and you will find a cavity large enough for your full charge.

It is better to avoid springing holes if you can, on account of the fact that the cavity often is enlarged too much, and the surrounding earth is loosened so much as to injure confinement. (See page 57 on detonation). A great deal can be done by scraping the small auger hole out to 2 or 3 inches in diameter at the bottom and then causing the

sticks to enlarge and fill the hole solidly. To accomplish this enlargement of sticks, slit their wrappings 3 or 4 places lengthwise, from end to end. Then press them home with the tamping stick. They will expand and shorten. Four to 6 sticks in this way can be got into the full length of two.

Still another way is to take the explosive entirely out of the stick wrappings, and with the help of a tin or paper tube, such, for instance, as calendars are mailed in, funnel it down to the bottom of the hole. But neither this method nor slitting the sticks is wise in wet holes. It is true that nitroglycerin powders will stand considerable water, but the safe rule in wet blasting is to leave the sticks intact. Ammonia powders or dynamites will not stand wetting inside the paper of the sticks without damage. (Never under any circumstances cut, break, unwrap or punch holes in explosive that is frozen. You invite an explosion in your hands when you do).

When there is more than one stick in the charge, place the primed stick on top of the others—put it in the hole last or next to last—when using the cap-and-fuse method of firing.

Be sure that all parts of the charge are in firm contact. It will not do to have air spaces, or dirt, or wrinkled paper between the sticks. While all the powder likely would go off under these conditions, it will not do as much work as it should.

The sticks of explosive may fit tightly in the holes. In that case do not ram or pound them, but press firmly against them, one at a time, with the tamping stick. Press the explosive into tight contact with the sides all round, at the bottom of the hole.

Tamping

Tamping

Tamping is a necessity. The charge should be tightly confined. It is only in springing holes and sometimes in digging post holes that no tamping is advisable, and in ditching that the quantity needed is less.

When the explosive is in place at the bottom of the hole, start the tamping by rolling in some loose ground. Keep the tamping stick working up and down to seat this ground against the explosive, though make no effort to get it tight till there is a few inches or so over the explosive. An exception to this rule is in the case of blockhole blasting of boulders and ledges, when damp clay tamping should be packed solid all the way down to the explosives. The rule for the least contents of tamping that will do good work is that it should be 6 or 7 times as deep as the hole measures in diameter.

If the tamping is less than this, the best results will not be secured, hence deep holes often are necessary for the sake of confinement of charge as well as to contain the amount of powder used.

Hold the fuse to one side with one hand while the tamping stick is worked with the other hand. Rake the dirt to the mouth of the hole and be careful to get in the hole only earth—not clods, sticks, grass, etc. Be very careful not to damage the cover of the fuse with the tamping stick.

Fill the hole to the top with tamping, and make it tight. The best material for tamping is moist clay. Tamping material always is better when made *wet* enough to ball. In fact, there isn't much better tamping than water itself in the hole, when it can be made to cover the charges deeply enough. Use the heaviest earth within reach, and if it is dry, better carry some water for wetting it.

Firing

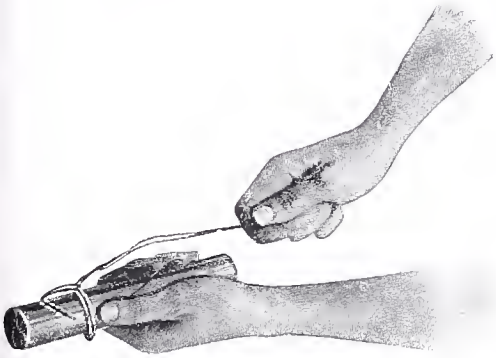
The free end of the fuse will stick out of the hole filled with tamping, say about 4 inches. Your remaining work is to set fire to the powder in the fuse, till it begins to spit continuously. Split the end of fuse with your pocket knife to make it light easily. Put the flaring head of a freshly scratched match against the powder exposed by the cut. (See page 60.)

Preparing Charges for Electric Firing (Making Primers)

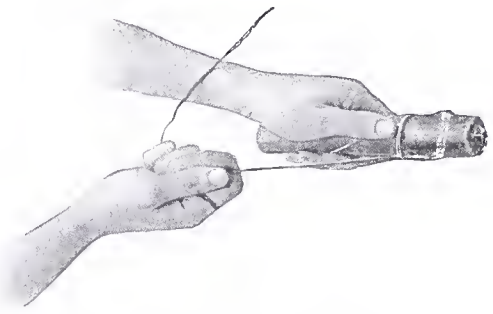
Up to this point in the directions for preparing charges the text has spoken only of caps and fuse. When the firing is to be done with an electric blasting machine instead of fuse, you must use electric blasting caps.

These come from the makers with the wires already fastened in them. (See pages 66 and 67.) They are ready to be inserted in the stick of explosive without any preparation such as ordinary caps and fuse require.

Make a slanting hole in the stick of explosive just as is described on pages 46 to 48. Into this insert the electric blasting cap, letting its wires project just as the fuse does when fuse is used. Then tie the wires to the stick with a string as fuse is tied, to prevent the cap from being pulled partly or entirely out of the hole.



Bad method of fastening wires.
It is better to tie them.



Bad position of cap in stick, and of cap wires.

It is a little difficult to tie the wires tight enough with a string to prevent slipping. Another way to fasten them securely is to pass the wires through the stick. To do it punch a hole straight through the stick of explosive about the middle. Double the wires about 6 inches back of the cap and pass the doubled end through this hole. Then loop the doubled ends from the other side back round the lower end of the stick. Take up the slack in the wires and you will have a sure fastening. The cap can be inserted in the stick at another point, in a slanting hole, just as described previously.

In fixing wires of electric blasting caps to sticks, avoid crossing them and avoid bending them sharply or in any manner that will break their insulating. If the insulating is broken it likely will cause a short circuit, which will result in a misfire. *Never take a half hitch about the stick with the wires.* Do not pull at the wires and the cap, because to do so may break the fine bridge wire that causes the cap to explode when the current goes through.

Load these primed sticks the same as is directed for fuse primed charges. Be careful to avoid rupturing the insulating on the wires with small stones in the hole or with the tamping rod.

The finishing of the tamping leaves two wires projecting from each hole. They must be connected with the blasting machine or other source of current with connecting wire and leading wire, in the manner described fully on pages 62 to 65. Further discussion is not needed at this point.

Some General Suggestions

In priming sticks of explosive with fuse and blasting cap, you must be careful to avoid permitting the fuse to touch the explosive. High explosives will burn like gasoline or coal-oil. They are very easily set on fire by sparks spitting from fuse. When they are burning the explosion will be very much weaker than it otherwise would be, and will give off noxious gases.

A very frequent cause of misfires is the bending, kinking and crooking of fuse. This is especially frequent when the cap is inserted in the center of the end of the stick of explosive and then carelessly forced over against the side of the hole by the tamping stick and tamping material. Keep the fuse straight, and never under any circumstances lace it through the stick of explosive. That is a sure cause of trouble.

If it becomes necessary to remove a cap from a primed stick of explosive, do it gently and carefully, and unless the cap and fuse are immediately to be inserted in another stick, destroy them both by lifting a shovelful of earth and putting the cap under the ground in the hole, after which light the fuse and go away.

It is better not to lift or carry the primed stick of explosive by the fuse or wires when it can be helped. When a practice of carrying primed sticks by the fuse is made, misfires and poor explosions will be caused, not every time, but often enough to make it wiser not to do so. The cap often is pulled back in spite of the tie string.

Where explosives that are subject to water damage are used in work that is wet, matters can be helped by making the sticks waterproof with tallow, paraffine or other suitable material. It is practicable to stop all the seams on the sticks, load and fire without delay, even with explosives that would be put out of business if the water got at the actual material instead of only at the wrappings of the sticks. Pay particular attention to waxing or tallowing the place where the cap and wires go into the stick.

When doing wet blasting, use every care to keep the outer end of the fuse from dropping into the water or from resting on damp ground. The inner wrappings of fuse and the powder train itself take up water like a blotter. On a very foggy day it is well to keep fuse in a closed box. Mist and rain, of course, will damage it.

Explosives and Blasting Supplies

The catalogs of manufacturers are not intended to give all the fundamental facts about and the differences between the various explosives. To do so would take too much space. They give the trade names and the measurements and weights of sticks and boxes, demanded by purchasers, and are prepared on the supposition that blasters and buyers of explosives know what they need. This bulletin includes explanations of the names under which blasting explosives are made and marketed, outlines their properties, and makes clear the work and conditions for which each grade is intended and suited.

Explosives

There are scores of different kinds of explosives made and used for blasting purposes, and many dozens of different names used for them. The most familiar name of any explosive in America is dynamite. Another familiar term is powder. Other names are farm powder, quarry powder, contractor's powder, coal powder, stumping powder, Judson powder, gelatin, blasting gelatin, R. R. P., giant powder, blasting powder and dozens of others.

Names

Nearly every one of the explosives designated by these names are made in several strengths, and in qualities to suit varying conditions. For this reason figures and other marks are attached to the names to distinguish the grades. In addition to this some of the names are used to designate not only one certain explosive but several widely different ones. This is particularly true of the names dynamite and powder. The selection of names in the preceding paragraph is made for illustrative purposes, and is not to be taken in any sense as a recommendation of those explosives for any purpose. The recommendations are given in detail on other pages.

All blasting explosives are not made from the same ingredients, and they differ a great deal in many other ways than in quality, as quality is generally understood. You can buy cornmeal that is good, bad or indifferent, but when you buy explosives you will find there are few which can be classed as of poor quality. Nearly every standard kind and grade is of excellent quality for some particular purpose and condition. And practically every one can be classed as of poor quality for conditions and purposes to which it is not suited.

Differences

Nor is the difference one of size of stick or grain, as the case may be, though this is one element. The main differences are ones of strength, quickness or speed of gases, sensitiveness, resistance to cold and to water, density, fumes and cost. Some explosives are suitable for wet work, and others only for dry work; some are adapted to blasting hard, tough rock, others to blasting ground only; some freeze when chilled a little; others can be exposed freely without freezing. And it should be noted that many of the better explosives of to-day have been developed during recent years and are comparatively new. The explosive to buy for any particular work is the best one on the market for all the conditions involved.

Black blasting powder has been known and used for several hundred years, and it is practically the same to-day as it has been for a long time. It is composed of saltpeter or nitrate of soda, sulphur and charcoal. It does not vary in strength, and varies little in other properties.

Explosive Ingredients

The dynamites and high explosive powders have little or no relation to black blasting powder. They depend for their explosive force on other explosive chemicals the best known of

which are nitroglycerin and ammonium nitrate. It is not necessary in this brief description to name additional explosive elements.

The first dynamite was made in Europe by mixing nitroglycerin with a light spongy earth, and packing the mixture in paper tubes as sticks of dynamite and powder are packed to-day. Nitroglycerin itself is a wonderfully efficient explosive when it can be controlled, but it is so dangerous and unstable that it must be mixed and treated to make it safe enough to handle.

As other explosive chemicals become better understood, it has been found of advantage to substitute materials that are explosive for the light earth used to absorb the nitroglycerin. And more than that, the nitroglycerin itself has been displaced to varying degrees in some of the powders and dynamites by ammonium nitrate and other materials. Few blasting explosives contain no nitroglycerin at all, but many contain only 4 or 5 per cent. of it. Each of these combinations of materials, or formula, has its own peculiarities in addition to variation in strength, all of which information it is well for a buyer and blaster to understand.

The explosives marketed as "straight dynamites" and "straight powders" are made from nitroglycerin. Those made from an ammonium nitrate base are called by many manufacturers "extra" dynamites and powders. Gelatin dynamites and blasting gelatin are nitroglycerin explosives in which the nitroglycerin has been combined with gun cotton. The various special mine, quarry, stumping, farm and other miscellaneous dynamites and high explosive powders on the market are not so named that their ingredients can be determined without a statement from their makers.

The power of an explosive and its violence are two different qualities. The power, or direct strength, is due to the volume of the gases. If a pound of a certain explosive gives, for instance, 1,000 cubic feet of gas when completely detonated or fired, while a pound of another explosive gives 500 cubic feet and a pound of a third gives 2,000, the lifting power of each explosive will be in direct proportion to its gas volume.

Strength and Quickness

But the violence of the gases depend, not on their volume, but on their speed. If they are comparatively slow in forming and in forcing their way out of their confinement they will break out large cracks and escape through them, pushing the material aside. If they are very fast or quick, they will grind and pulverize everything they come in contact with, and throw out the whole side of the confining material, but will not crack it so far.

The matter can be made clear by comparing a push with a blow of a hammer. Both may have equal power, but the effects on a block of wood, for instance, at the point where they are applied are very different. The push will move the object almost without marking it. The blow may move it, but it is sure to leave a mark of greater or less depth, depending on the nature of the hammer and its speed. A still better comparison, perhaps, is that between the blow of a sledge and of light hammer. It is possible to hit a blow of as much power or weight with one as with the other, but the material at the point where the blow lands with the light hammer will be badly dented, or maybe broken. The reason is that the light hammer moves with much greater speed.

In quarries blasters make use of these facts in order to get the rock broken out in pieces of the size preferred. When they want large pieces they use an explosive with sufficient power to break the rock, but, comparatively speaking with a slow speed of gases; when they want small pieces and much shattering, they use an explosive of the same or greater power but with swift and violent gas action.

For each result and for each material a certain power is required and a certain quickness of the gases is best. By way of illustration, take soil blasting for tillage purposes. There is no object in violently grinding the earth at one spot while surrounding earth that might be reached is left untouched. A proper explosive for this purpose is one that will have enough pulverizing action, that will lift and shake up the soil, and that extends its effects for long distances. For an example of the other extreme, take mud-capping rocks. For this work the explosive cannot be too violent in action. The gases, backed up by the rapidly yielding wall of air behind them, must strike the rock a crushing blow in the minimum of time.

Nitroglycerin and ammonia powders and dynamites, for all practical purposes, are of equal strengths when of equal markings. The strength is indicated accurately by percentage figures.

Nitroglycerin explosives are uniformly quicker and more violent in action than ammonium nitrate explosives, and the more nitroglycerin there is in the explosive the quicker it is. The ammonia explosives are not as quick, in any strength, as the corresponding nitroglycerin explosives. Therefore a 50% nitroglycerin powder is more violent than a 50% ammonia powder, and a 20% ammonia powder is much less violent than a 50% grade.

When the object is to shatter and reduce to fine fragments the material to be blasted, the proper explosive is a quick one, while when the object is to lift and shake up the material the best explosive is a slow one. (See table on page 57, also detailed recommendations on pages 37, 53 and 57.) But there are other factors that must be considered.

Nitroglycerin explosives resist water better than ammonia explosives, but if the cartridge wrappings are not broken or opened, ammonia dynamite or powder can be loaded in wet holes with entire satisfaction. The firing should not be delayed any longer after loading than necessary, and it is wise to plan the work so that it may be done at the longest within a half hour after loading. Storage in a damp place will weaken explosives, especially ammonia explosives.

Gelatin explosives resist water very well, and may be loaded in wet holes, or under water, with assurance that they will explode with their full power. Blasting gelatin is entirely water-resisting.

Explosives will freeze, and when in this condition are dangerous, and cannot be fired properly, if at all, with a cap of any kind. They *must* be thawed and they must be handled very carefully if they are to be used. On no account attempt to cut the wrappings, to break a stick, or to handle the frozen explosive in the ordinary way. (See pages 58 to 60 for directions for thawing.)

Regular nitroglycerin explosives are quickest to freeze. Others, known as "Low Freezing," will stand much lower temperatures without showing trouble in this respect.

Freezing

Ammonium nitrate explosives also will freeze, but not quite so quickly as nitroglycerin explosives. They too are made on both regular and low freezing formulas. The low freezing ammonia will stand more cold than the low freezing nitroglycerin.

The regular explosives will freeze at temperatures of 45 to 50 degrees. The low freezing explosives will not freeze and become solid till the thermometer gets down to at least 25 degrees, and in practice many of them can be used right out in the open without any trouble when the temperature is down to zero and below. The length of time the powder is exposed to the cold has much to do with its freezing.

The safety point for both low-freezing explosives and regular explosives is not a matter of rule, but of watching the explosive. When high explosive

powder or dynamite is frozen, the sticks will be hard, and when it is partly frozen they usually will have a mottled appearance on outside of the paper wrappings. The hardness may only be in spots. When not frozen, the sticks should be a little soft all over. No explosives should be handled much, cut, punched, rubbed, broken or loaded when they are frozen. They cannot be exploded satisfactorily and such acts are dangerous.

In cold weather always use the low freezing grade of explosives, for the regular grades may freeze in the holes before they can be fired. It is a good plan to use the stronger caps, say No. 8 (see page 66) in cold weather. When a charge of explosive is chilled but not frozen it can be fired satisfactorily by a heavier impulse (blow and heat) than ordinary, such as a fresh No. 8 cap gives. The low freezing explosives do not differ in action from the regular explosives, and are just as efficient.

The gases of explosives naturally are more or less objectionable when breathed. Some of them are poisonous, others are merely disagreeable. When explosives are used out in the open the gases are taken up by the air so quickly that none of them give any serious trouble, though they do cause headaches. It is only in tunnels and deep shafts where the air is confined that the matter of fumes is important, not on farms.

Special explosives have been developed for tunnel and mine work, but they are not important in agricultural work. The only fact about fumes worth knowing in farm blasting is that nitroglycerin explosives either in the form of their gases or when absorbed through the skin will cause headache somewhat quicker than ammonia explosives. The so-called fumeless explosives always cost more than any ordinary dynamites and powders and are not suited to farm work. Farmers will do well to buy grades of explosives suited for their special purpose.

Other Properties

Dynamites and most high explosive powders are light-colored materials that look like fine, sticky sawdust, and they always are packed in "sticks" made with cylinders of tough paper. These sticks vary in diameter and length. The standard is 1¼ inches in diameter and 8 inches long. This is the size carried in stock by dealers and in the magazines of the makers. You can get special sizes of sticks if you need a considerable quantity, varying from ⅞ of an inch in diameter to 4 inches. Sizes other than the standard 1 ¼ by 8 inch may cost more per pound than the standard owing to higher packing cost.

Appearance of Explosives

Dynamites and high explosive powders are packed in wooden boxes containing 25 pounds or 50 pounds, as you prefer. A 50-pound box of 20% ammonia powder or dynamite will contain about 105, 1¼ by 8 inch sticks. If of 20% nitroglycerin, it will contain about 98 sticks. If of gelatin dynamite, or blasting gelatin, it will contain about 88 sticks.

A word should be said here about the cost of explosives. No quotations can be given because the prices vary in different parts of the country and from time to time. The ammonia products usually are cheapest. The cost of course follows the percentage strength, the low percentages cheaper and the high percentages dearer. Gelatin explosives cost about the same as straight nitroglycerin explosives. The special explosives for use in mines, tunnels, quarries, railroad construction work, etc., often cost more than the explosives recommended here for farm work.

In buying explosives look first to getting the one that is best suited to the work to be done, and aside from that the cheapest one. There

would be no object in using a straight nitroglycerin or a gelatin explosive when one of the ammonia farm powders would do the work, for the former explosive cost much more than the latter.

To avoid "explosive misfits" it is well to consider carefully the nature of the material to be blasted, the conditions of weather, water, etc., and the results wanted. The kind of explosives to use depends on these factors. Keeping in mind the facts mentioned in preceding paragraphs, the reader will see that there is a type of explosive made for almost every condition and kind of work, and will understand why one will not suit the work of another.

As the briefest and clearest way of giving general suggestions for the type of explosive best for different agricultural work, a table follows: (Detailed recommendations are given on pages 37 and 53.)

Explosives Recommended for Different Work

Stone blasting—mudcap	Straight nitroglycerin or ammonia dynamite, 50% or 60%.
Stone blasting—undermine	To break, same as for mudcapping; to throw out, use any dynamite or powder of 20% strength.
Stone blasting—blockhole	To shatter well, any high percentage dynamite or powder; to break into large pieces, 20% ammonia dynamite or powder.
Soil blasting—for subsoiling and for tree planting	20% ammonia dynamite or powder.
Ditching—electric firing	20% to 40% ammonia explosives; (nitroglycerin is equally effective); in loose dry ground, high percentage nitroglycerin explosives.
Ditching—transmitted detonation	Straight nitroglycerin dynamite or powder, 50% strength.
Stump blasting—in medium and heavy soils, wet or dry	20% nitroglycerin or ammonia dynamite or powder.
Stump blasting—in dry sand and other light soil	50% nitroglycerin or ammonia dynamite or powder.

If you are in doubt as to the best explosives for your particular work it is well to write to the manufacturer you prefer, asking which of their grades and brands would be most suitable.

Detonation

Firing, Exploding or Detonating

It is well known that black powder is fired by a spark, and that dynamites and high explosive powders cannot be fired by a spark but require a shock and heat. It is not so well known that there are great differences in the nature and effect of the explosion of any powder or dynamite, due to variations in the way it is fired.

An explosion of powder or dynamite is the result of a very sudden creation of a great volume of gas from a smaller volume of powder. The kind and amount of gases produced by any

high explosives depend on the kind and amount of shock used to fire the charge, and on its confinement.

The effect of lighting a piece of unconfined dynamite with a piece of fuse without a cap on, is that the dynamite will burn fast without exploding and make a dense smoke which has a bad smell and produces severe headaches. This is simple combustion. If the piece of dynamite is confined closely and lighted in the same way it will explode, but will give off similar bad fumes. If a weak cap is used on the fuse, or the dynamite is set off by a fall, the dynamite will be partially detonated, and explode with considerable force, but it still will give off the bad fumes and smoke. The same piece of dynamite fired with a No. 6 or 8 cap will be completely detonated, and will explode with great violence and force, even when unconfined, except by air, and will give off very little smoke.

The last-named explosion is detonation. It is produced by a violent shock in connection with intense heat. Nitroglycerin is 5 times as strong as black blasting powder when exploded by fire, and 10 times as strong when detonated. This explains the enormous force given by detonation as compared to simple explosion.

But detonation itself is no set thing that always takes place the same. There is good, or complete, or full detonation, and there is partial detonation. In case of incomplete detonation, or any detonation at a less speed than the greatest for any particular explosive, the gases formed are not what they should be. For one thing, they are more noxious or poisonous. The more powerful and severe the blow delivered by the cap, the more quickly does the chemical action take place in the explosive. It is only when high explosives detonate with their greatest speed that their maximum power is generated.

Air spaces about the cap in the stick of explosive cushion its blow and weaken detonation. It is the nature of the initial detonation of the powder right around the cap which governs the nature of the explosion of the whole charge. A blaster should understand the importance of setting up *complete* detonation in order to get the greatest amount of force out of explosives. Sometimes explosives lose as much as 20% of their effectiveness when fired with weak caps. Lack of confinement has a similar effect. Sixty per cent. dynamite poorly detonated is less effective than 40% well detonated.

When explosives become chilled it is difficult to detonate them properly with the usual cap, hence the advisability of using a very strong cap in cold weather—a No. 8. Many of the holes are frequently loaded for some time before firing, and even if the powder is soft and normal while charging, it afterwards becomes somewhat chilled in the cold ground.

Cap Means Detonator

Throughout this and other bulletins in this series, the terms caps and electric blasting caps are used in speaking of the exploders used to fire the charges of dynamite or powder, although in the field and among manufacturers the same articles are called by the terms "detonators," or "electric exploders."

Thawing Explosives

It has been pointed out (on page 55) that regular explosives chill or freeze at temperatures of 45 to 50 degrees. With the increase in the number of low freezing explosives that seldom need thawing, the necessity for doing the thawing on farms is not as frequent as it used to be.

Frozen dynamites and powders are dangerous materials, and whenever the temperature is near the freezing point for them, the sticks should be

inspected before using to see if they show any of the hardness that indicates chilling. If so, handle them very carefully till they are thawed. Dynamites and high explosive powders will be a little soft to the pressure of your thumb when they are not frozen.

Frozen Explosive

Frozen explosives are dangerous because they are very much more easily exploded in the course of ordinary handling. They are more sensitive to friction and to blows of tools. The sticks may explode when dropped to the ground or floor, when sticks are broken in two, when wrappings are cut with a knife, when cap holes are punched with a stick, or when they are shoved into a hole with a tamping stick. At the same time they are so much less sensitive to the direct shock of a detonating cap that they cannot be fired properly with a cap. Therefore the rule must be laid down that frozen sticks of high explosives never must be cut or ruptured or used until they are thawed.

When nitroglycerin freezes it crystallizes, therefore the nitroglycerin in dynamite or powder tends to separate from its absorbing materials into small crystals. When the dynamite is thawed slowly with sticks lying on their sides, the nitroglycerin is reabsorbed as fast as it liquefies. But when thawed too fast, the nitroglycerin is liable to run out of the sticks before it is reabsorbed. Quick thawing will damage explosives a great deal more than they would be damaged by freezing followed by long, gradual thawing.

One type of thawer on the market.

Thawing is a dangerous operation when not done right. It probably is correct to state that more accidents with dynamite have occurred in the course of improper thawing than for all other reasons put together. At the same time proper thawing is entirely safe.

Two of the most frequent causes of accidents while thawing explosives are in putting the sticks into water or steam, and putting them on hot stoves or stones. Water, and especially hot water, forces the nitroglycerin out of the sticks. The free nitroglycerin goes to the bottom, and explodes at the time of the first increase in heat, or first light blow. When sticks of explosives are laid on hot material the nitroglycerin also runs from the paper wrappings and drops of it fall to the stone or metal. This almost always causes an explosion. At about 350 F. degrees of heat, which is only a little more than that of boiling water, the nitroglycerin will explode without a shock.

Causes of Accidental Explosions

Examine your explosives a day or so before you are ready to use them, and if they show that they are frozen, proceed to thaw them in one of the following ways: Use only a *DRY* warmth. Use no temperature higher than is comfortable to the hand, or the limit may be set at 100 or 110 degrees. Use no heat of any kind that cannot be controlled with certainty. If you do this you will be safe.

Safe Thawing

Every large maker of explosives will supply thawing apparatus that is safe. Sometimes this is a double kettle arranged so that the sticks of explosives can be placed in the inside vessel, while the outside vessel can be filled with warm water and a blanket can be spread over the top. Other more elaborate thawers consist of a vessel containing watertight tubes just big enough to hold

sticks of explosive, running through a space to be filled with warm water. The catalogs describe these ready-made thawers in detail.

Home-made thawers can be arranged with two buckets, one small enough to hang inside the other. Put the sticks inside the small one and warm water around the outside, in the big bucket. Another good way is to put a five-gallon can of warm water inside a barrel, or box, and pile the sticks of explosives in the barrel around the can. The top of the barrel should be covered with a blanket. Or put the water in the barrel and the explosives in a can or bucket. A small closet of course can be used instead of a barrel. A can of warm water can be set inside a magazine to keep the temperature up.

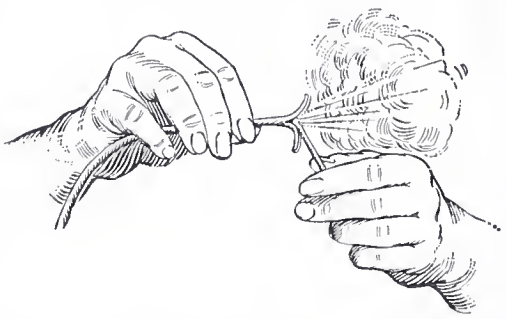
The old-fashioned manure pile method of thawing is reliable and safe, though a good deal of trouble. This consists in burying a box somewhat larger than a box of explosives in fresh horse manure, and placing inside it the box of explosives to be thawed. A foot or more of manure must cover the box, and a small pipe or tube should be inserted for ventilation. The manure must be fresh. Allow at least 10 hours to thaw a box of dynamite or powder in this way. Twenty hours is better.

The box of explosives can be taken into any warm place that is dry, but if this is a building you must take your own risk of fire and accident. Watch the box and the sticks to see if the freezing and thawing causes the sticks to leak free nitroglycerin. If any of this leaks out of the stick and gets on the floor it must be washed up according to directions in paragraphs on storage. (Pages 69 and 70.) The sticks of explosives had better be piled irregularly rather than in tiers, for thawing. They will rise in temperature quicker in this way. They always must lie on their sides rather than stand on end.

Sticks on Sides

Electric and Fuse Firing

The very best way to light fuse is to split the end for an inch or less, and stick the burning head of a freshly scratched match right against the exposed powder at the head of the split. This will light the fuse even in a strong wind.



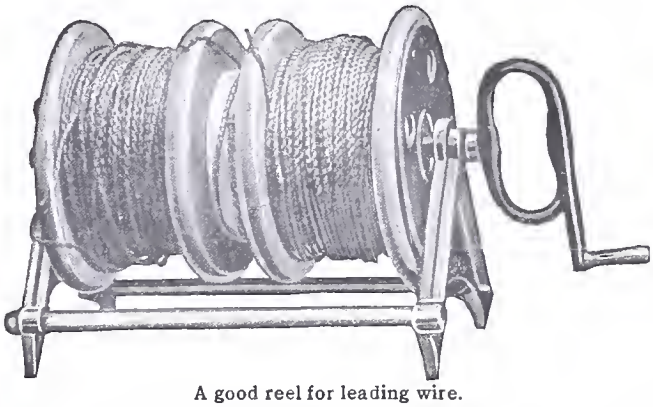
Where there are very many fuses to light in succession, as in subsoiling, it sometimes is of advantage to use a gasoline or other torch, holding the hot flame under the fuse for an instant. Whatever the method, do not leave till you see the fuse spitting sparks and smoke swiftly and regularly. Further di cussion of fuse firing, except as to its adaptations, is not needed.

Fuse and Cap Firing

Farmers who have only a few stones or stumps to blast, or who are planting a few trees or doing a little subsoiling, will not need any other method of firing than by caps and fuse. Ditch blasting in ground not watersoaked demands electrical firing, while the blasting of large stumps, particularly if green, and in sandy soil, as well as the blasting of large rocks, is made easier and cheaper by electrical firing. For large amounts of almost any blasting except that of tree beds, subsoiling and very small stumps and isolated small

Electric Firing

boulders, the purchase of an electric blasting machine and the necessary wires is justified by the advantages of the electric methods of firing.



A good reel for leading wire.

Advantages

The primary reason for the superiority of electric firing over fuse firing is that several charges may be exploded at once; the different charges will increase the efficiency of each other. Thus in ditching, you can fire many charges in a row and make a perfect ditch. In stump blasting several small charges very often will take a stump out better than one large charge, and in orchard, and garden subsoiling the simultaneous blasts frequently are of advantage.

Electric firing is more certain when the charges are under water. The danger from misfires due to moisture as well as from some other cause is reduced. Should misfire occur, you are safe in going to the charges as soon as the wire is disconnected from the blasting machine. With a fuse you must wait some hours to be safe. When several charges, as for instance, several boulder blasts are to be fired, you can make one trip to safety do for the lot, instead of having to travel back and forward for each shot. Finally, the intelligent and careful use of electric firing, with its possibilities of two or more small charges doing the work of one large one, and its other economies, will save considerable explosives.

All the makers of explosives supply electric blasting machines. The machines are small boxes of wood or metal, containing a modified magneto with a handle on top that you either push down or pull up, depending on the make of machine, to operate and to fire the charges. The machines are made in various sizes and capacities to fire 3, 10, 30, or more charges at once. The 10 charge machine weighs about 10 pounds. Full directions for operating and caring for the machines always accompany them.

Electric Machine

For electric firing, in addition to the machine, you will need electric blasting caps, connecting wire and leading wire. The leading wire is copper wire large

Duplex Leading Wire. (Actual size.)

enough to carry the amount of current required for the number of charges to be fired simultaneously. It is covered with insulating material, and is made strong and durable to stand much use. To make the circuit from the blasting machine to and through the charges and back again, you must have two strands of leading wire. It comes from the

Wiring

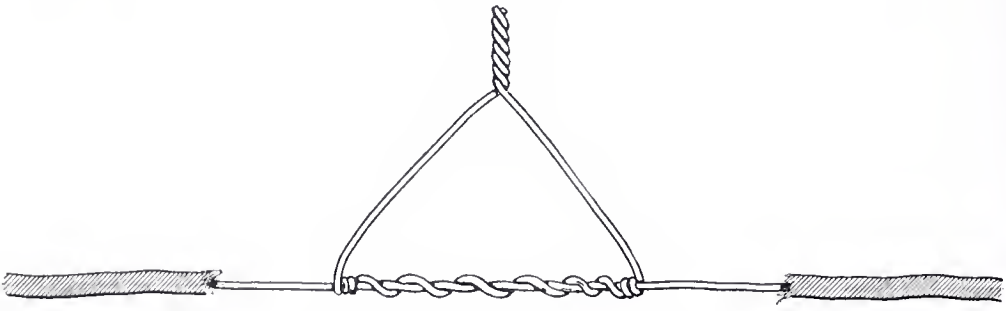
explosive makers in single-strand form, which must be doubled, and in what they call duplex form, which has two strands of insulated wire twisted together or wrapped together under one cover.

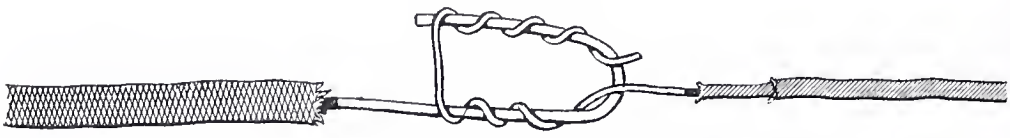
Connecting wire comes on spools.

Electric Blasting Caps

The two small copper wires that are fixed in the electric blasting caps (see page 66) should be long enough to reach out of the holes. They may be bought in a variety of lengths, but 4 or 6 feet are regarded as standard. If the charges are close enough together so the wires can be connected, no connecting wire will be needed; but whenever the distance between is more, the charges must be connected, and connecting wire is the right thing to do it with. There is no particular limit for the distance between charges that may be connected for firing together, up to 25 feet or more.

A very bad connection—a cause of misfires.

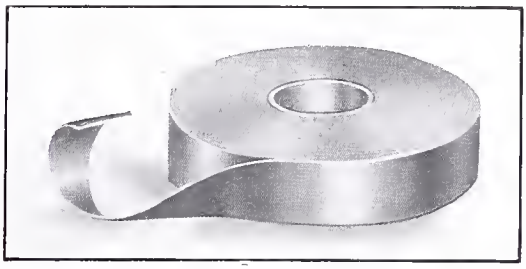

Good connection for electric cap wires


Good connection for small cap wires and large leading wire.

Wire Connections

The diagrams in these pages will show how to make electric wire connections. Cut away the insulating on the wire ends and wrap the ends together tight. Wrap them for two inches. Looping the wires will not do. Be careful to scrape with a knife or stone the wire ends to make them bright before wrapping them together. Corroded or dirty connections are a cause of misfires. If the leading wire gets broken and must be spliced, solder the connection after wrapping the ends together, then wrap the joint with tape to

insulate it. Ordinary tire-tape is good, but a better way is to wrap the joints with special rubber tape underneath and to cover this with the tire-tape.



Tape for wrapping joints and broken insulating.

When only one charge is to be fired, connect the ends of the 2 strands of the leading wire to the 2 electric blasting cap wires and connect the other leading wire end to the blasting machine posts. The connection with the electrical blasting machine should be made the last thing before firing, after you are sure that the charges are all ready and after every person and animal is out of the way of the flying pieces.

When the blast is all connected together ready to fire, except attaching the leading wire to the machine, give the handle of the machine one or two light strokes, to make sure that it is working smoothly and to charge the magnets. Then attach the leading wires to the binding posts on the machine, making sure that both the binding posts and the wires are bright and clean where they come together. Raise the handle of the machine to its full height and push it down with speed. When the handle starts on its downward stroke, the pinion immediately clutches the armature and starts the generation of current. The current, growing stronger as the stroke proceeds, causes considerable resistance toward the end of the stroke. The current generated is directly in proportion to the speed with which the handle is pushed down, especially just before reaching the bottom. Any let up toward the bottom will cause a drop in the current and may result in misfires. Therefore, make it an invariable rule, whether the shot be large or small, to bang the handle down hard and carry the stroke with all possible speed to the bottom. Try to knock the bottom out of the box. Machines which operate by the twisting of a handle must be handled equally quick.

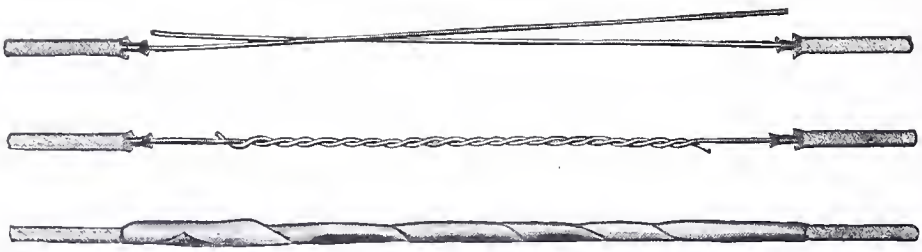
Very best wire connection, ready for soldering if need be. (Excellent for leading wire.)

When more than one charge is to be fired the different charges must be connected together. The diagrams will help you to understand how this should be done. For nearly all agricultural blasting the connection in one series is the best—that is, connecting each charge to the next one and so on until they are all joined, with one loose electric blasting cap wire from the two end charges of the series. (See diagram A and D, page 64.)

Once in a while, where the series is long and the charges are in a line, you can arrange to have the 2 loose wires at the same end of the series by making the connection, not to each next charge in the row, but to the one beyond and at the farther end doubling back and connecting the missed charge. Do not use this method where it involves many splices with connecting wire.

Connections in parallel sometimes are desirable in the case of ditches, or other extensive blasting. To make them run a piece of wire away from one leading wire strand along the lines of charges and connect one wire to each charge. Then run another similar piece of connecting wire connected to the other strand of leading wire, and attach to it the other cap wire of each charge.

But to fire charges by means of parallel connections takes so much electric current that a blasting machine cannot be used. Generally speaking, parallel



Method of wrapping wires together to make electrical joint, and of taping joint.

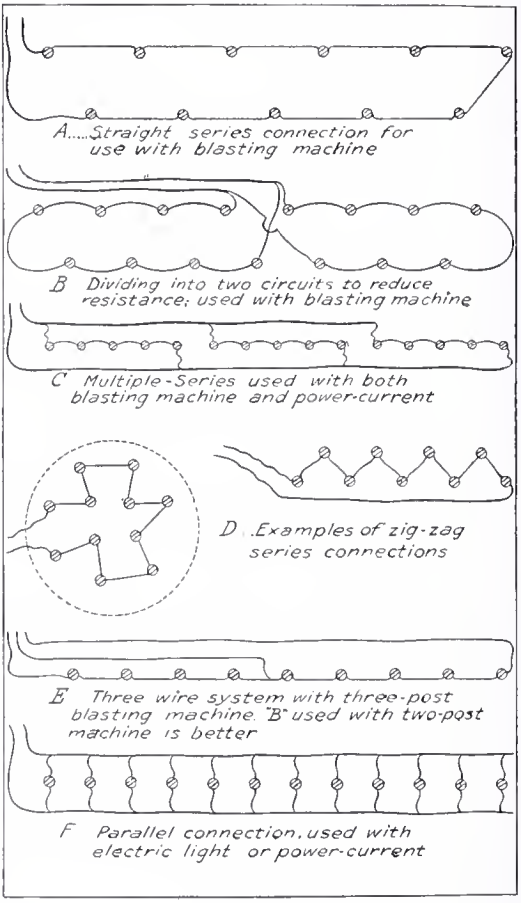
connections require current from an electric light or power plant. If your work is such that the charges cannot be connected in series or that parallel connections are desirable, it is well to communicate with an expert or authority on electricity for special suggestions and advice as to how best to fire your charges.

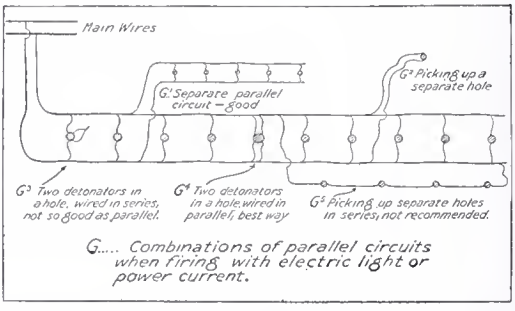
Current Required

In a bulletin of this size it is impossible to give a comprehensive statement of electric firing. But to give some idea, it can be stated that an electric blasting cap requires 1 to 1½ amperes to insure firing. This amount of current will fire one cap or many in a series. To force this amount of current through the wires requires a certain voltage, the amount depending on the size and length of all the wires, and on the joints. One bad or poorly wrapped joint will increase the resistance of the circuit more than several caps. The voltage of the current required to fire any circuit usually can be computed by an expert when the details of the wiring system are explained to him.

When charges are connected in parallel, instead of series, or in multiple series (see diagram C), each circuit requires 1 to 1½ amperes of current. That is, each cap requires 1 to 1½ amperes when connected in parallel. The voltage required, of course, depends on the resistance of the wires. A very much greater current than of 1 to 1½ amperes will do no harm; in fact it is desirable.

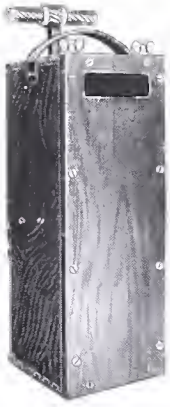
Electric blasting machines are constructed to give a sufficient amperage and voltage for





Ways of connecting up charges for electric firing.

firing properly the number of caps specified as the capacity of the machine when connected in a series. If too many caps, or more than usual wiring is connected to any machine, misfires will result. Other current can be used in place of that supplied by a machine, provided it has enough and not too much amperage and voltage. Too great a current will burn out wires without firing all the charges. Too little current sometimes will do the same, or it may do nothing. In emergencies dry cells or wet batteries can be used by skillful operators to fire a few charges, when great care is taken to have the wiring arranged for the purpose. Before attempting to fire charges with batteries of any kind, learn the amperage and voltage of their output and see that your shots come within their limits. The use of batteries is more expensive than the use of electric blasting machines.



Two post electric blasting machine—push down type.

Bare connections at the charges or back along the leading wire should be raised off the ground by stones, sticks or piles of dirt placed under insulated parts of the wires at each side of the splice. During a thunder storm, do not stand near any of the charges that have been connected. Avoid dragging the leading wire over bare or rough ground as much as possible, and particularly avoid kinking it. Be careful not to break or tear or scratch the insulating of any wires.

Do not attempt to fire through a long length of leading wire wound in a coil or on a reel. The induction, leakage or short circuit of current in the coil of wire causes the blasting machine to deliver a slow discharge, which is fatal to proper firing. Leading wire that is watersoaked or that is covered with mud will lose a considerable part of its current.

Misfires

Nearly half of the accidents noted each year in blasting operations are the result of attempting to examine misfires too soon. If misfires occur with fuse firing, stay away from the shot at least 2 hours. It is better to wait until the next day, for the spark may linger 24 hours and still cause an explosion. (See page 52.) Rock and stump misfires are to be avoided especially. When you are firing the charges electrically, you may approach the shot with entire safety as soon as the lead wire is disconnected from the blasting machine.

Misfires are due to the following named causes. The remedies for them are care in preparing the charges and in loading, the details of which are given in the proper chapters.

With cap and fuse firing, misfires are caused by having the end of fuse pulled back a little from the bottom of the cap, by crimping the fuse too tightly with a groove crimp and shutting off the spark, by damp or wet fuse, especially at the end of the cap, by defective cap, by the cap getting pulled out of the explosive, by kinked, damaged, broken or pinched fuse, by failure to light fuse. A great many misfires were never fired at all. With electric firing the reasons for misfires may be damaged wires in the hole, causing short circuits, defective caps, overloaded blasting machine, cap pulled out of explosive, bad wire connection at some point, or broken wire.

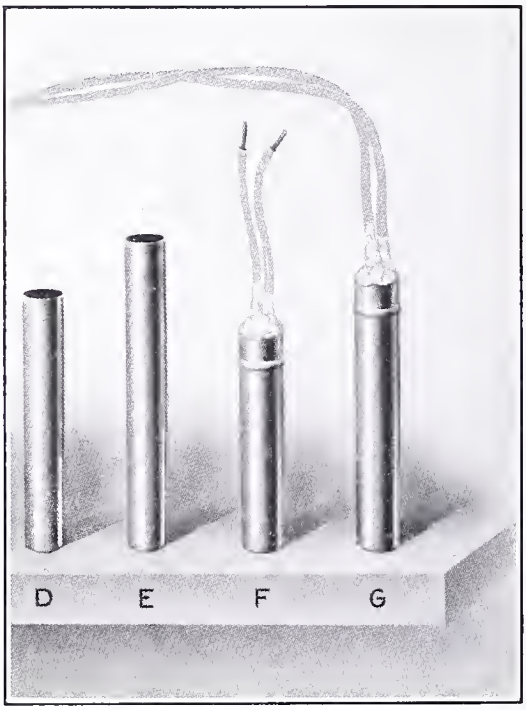
If you find after due time that for some reason the charge cannot be fired by lighting the old fuse or by sending current through the wires, you must deal with a real misfire.

The best thing to do is to put in another, lighter charge in a new hole made 6 to 12 inches of the original one. The explosion of the new charge will explode

the old one. Never touch the tamping in the old hole unless you know just how deep it is, or how many inches of it there are above the charge. Once in a while the tamping may be dug out of a blockhole misfire. It seldom pays to do this in stump blasting, and never in ditching, or soil blasting. At best it is a dangerous operation. Mudcap charges can be opened and new primers inserted without danger or difficulty. This should be done by removing part of the mud at another point, and inserting a new cap and fuse, or electric blasting cap, as the case may be.

Cap (Detonators)

Blasting caps are little copper tubes closed at one end, 1½ to 2 inches long and something less than a quarter of an inch in diameter. At the bottom is placed several grains of a high explosive that is very powerful and exceedingly sensitive to heat, shock and friction. This high explosive usually is fulminate of mercury, but often is other material. They are packed in small tin boxes, open end up, usually 100 to the box.



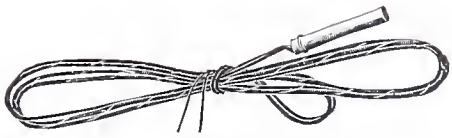
D and E are ordinary blasting caps; F and G are electric blasting caps, often called fuzes.

The purpose of the blasting cap is to supply the shock and heat necessary to detonate the charge of dynamite or powder to be fired. If it were not for safety in handling blasting explosives, they all could be made as sensitive as the material in the caps. But such explosives would be impossible to handle without accident. In fact, it would be impossible to handle the little bit of explosive in the caps if it was not protected by the copper shells. Even at that caps must be kept free from jars and from heat and sparks to avoid premature explosion.

The strength of caps is carefully regulated by the makers to fire the dynamites and powders on the market. The explosive material with which the caps are loaded is such as will deliver a shock and a degree of heat of the strength and violence required. The caps are numbered according to strength. All dynamites and powders used for agricultural blasting require at least a No. 6 cap. If they are chilled a little, but not frozen, they require No. 8. It is the part of wisdom to use No. 8 caps all the time if you can get them. They give you a margin of strength should moisture or other causes weaken them in storage.

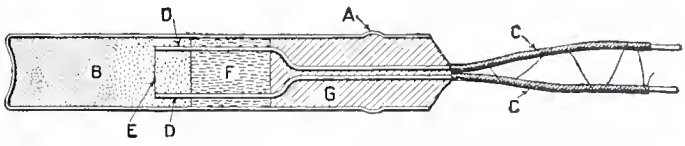
Blasting caps must be used with fuse. And before they are inserted in the stick of explosive they must be fixed to the fuse properly. (See pages 45 to 48.) It is the spark which travels down the fuse that fires the cap.

Electric blasting caps are made on the same principle as ordinary blasting caps. They have the copper tube, the explosive at the bottom, etc., but they differ in the way this explosive is fired. Instead of by a powder spark they are fired by a red-hot wire that is heated by an electric current.



Electric blasting cap or fuze.

Every electric blasting cap has fitted in it 2 small copper wires, which must be considered part of the cap. Down near the bottom of the cap is a delicate bridge of finer wire. The entire arrangement is held in adjustment and sealed by a casting of sulphur-like substance.

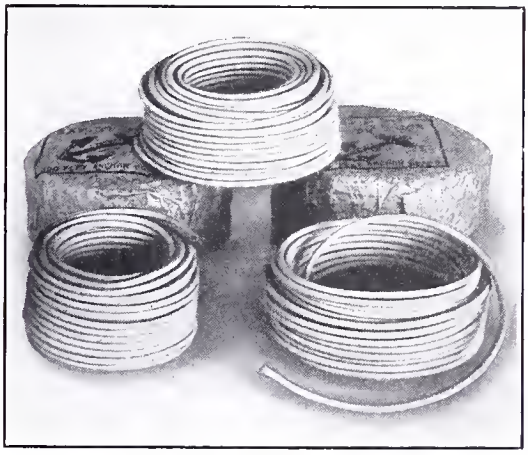


The interior construction of an electric blasting cap or fuze.

For fuse blasting you must use regular blasting caps, and for electric blasting you must use electric blasting caps. It is impossible to substitute one for the other. Never pull at the wires in an electric cap. It is dangerous and may loosen or throw out of adjustment the arrangement of wires inside. And never try to dig out the wires of an electric cap or to dig or to punch the explosive in the bottom of a blasting cap.

Fuse (Safety Fuse)

Fuse is used for firing black blasting powder and for firing dynamite and high explosive powders through the medium of a cap. It is made by enclosing within a covering a train of special black powder and an inflammable cotton string. The spark runs down this powder train.



Fuse as it comes in rolls.

The powder used in fuse is specially made for the purpose, is pulverized and is highly compressed by the covering of the fuse. The covering itself is made of varying materials, depending on the conditions under which the fuse is to be used. For dry work it is only enough to hold the powder in place and to keep the powder train from getting broken. For damp and wet work it is made waterproof by increasing the number of layers in the covering and by adding varnish, coal tar, as other waterproofing material.

There are many brands of fuse on the market. In buying fuse you must bear in mind the character of your work. For work that is entirely dry you can use ordinary cotton or hemp fuse with satisfaction, if it is large enough to fit a blasting cap snugly.

Grades

For work in damp ground, use a fuse in which the cotton or hemp is covered with one layer of waterproof tape or other material. This is called single-tape grade or may be known by brand name only. For work where the ground is wet, such as in stump and stone blasting in damp or wet weather, use a double-covered fuse—fuse that has two layers of tape or other material over the cotton

covering and waterproofing material added. For work where water covers the charges it is best to use fuse with three layers of tape or other material and full waterproofing. This is called triple-tape fuse or may have special brand names. When buying fuse for general farm work, it is well to get a waterproof grade, since it can be used for both wet and dry work.

Rate of Burning

Most reliable fuse burns about 2 feet per minute when in perfect condition. If it becomes damp, it burns much slower. Cases have been known where the spark smouldered in damp fuse for hours without traveling more than a few inches. Another source of uncertainty is where fuse has been pinched. It may take the spark a minute or an hour or a day to get past the pinched point.

When fuse is cold, it is hard and brittle, and may crack open when unrolled. If it gets too warm, its waterproofing material may penetrate to the powder train inside and ruin it; or the covering may first soften and then harden, in this condition breaking as though cold when unrolled. If grease is allowed on the cover it may combine with the waterproofing and ruin the powder inside.

Handling Explosives

Dynamites and powders in boxes can be hauled freely in spring wagons. You should see that no bolt heads or other metal parts project from the wagon boxes to strike the boxes of explosives. Sweep all dirt out of the wagon. Have the beds clean or covered with straw or blankets.

Go over your wagon and harness before you load dynamite to make sure they will not break down while you have the explosive aboard. Be sure you have the hitching straps or tie-ropes along, and do not leave the horses standing without tieing them securely. Break no colts while hauling explosives. If you use a motor, stop it and set the brake tight before you leave the load. In driving through a town stay away from dangerous crossings.

Keep the sticks of explosive in their original boxes until you are ready to use them. Don't have them around loose. In carrying them to the field, use a wood basket or a box and not a metal bucket. Always protect explosives from all possibility of being reached by falling sparks or from match heads or other source of fire. Rain, hot sun and the like must be kept away from explosives. Use care to lay sticks or set the boxes or baskets containing explosives where they will not fall down, be blown over by wind or knocked over by careless people or by animals. Cattle will eat sticks of dynamite, or powder, because of their sweet and salty taste. The explosive will make them sick, sometimes kill them.

Since nitroglycerin often will cause headache when absorbed through the skin it is best to wear gloves when handling the sticks. For this same reason some people punch holes for caps in the sticks with a piece of wood rather than with the handle of the cap crimper.

Caps should not be carried in the same basket or box as explosive, but should be carried separately. Take only enough along to do the work in view and carry them in the tin boxes they come in. Many serious accidents have been caused by blasters having loose caps in their pockets during work or afterwards. Sooner or later a chance jar is likely to set them off. When several caps have been taken out of the little tin box in which they come the rest will be loose and will rattle about. This should be stopped by filling up the empty space with paper.

The handling of caps is not dangerous provided you do it intelligently and with care. *Keep them safe from any jars or heat.* You can sometimes do

many foolish things with dynamite and powder without serious results to yourself, but not with caps. Letting a cap fall to the ground or floor likely will cause it to explode. For this reason you should keep the caps and explosives apart, in hauling, storing, and handling, bringing them together only at the last minute before you prepare the charge to be loaded in the hole. One cap can produce an explosion powerful enough to tear your hands off.

Handling

Electric blasting caps must be handled with the same care as regular blasting caps. All caps must be protected from dampness during handling. No trouble will be experienced if you use common sense at every turn, but thoughtlessness and carelessness in the handling of explosives will cause disaster. Bear in mind that when an accident happens with an explosive there is no time to save yourself, and no afterthought will prevent serious injury to you. Forethought is the thing with explosives. In an explosive you are handling an enormous strength. The fact that it occupies small bulk now should not interfere with your imagining it as an enormous engine with power enough to crush you easily, but under entire control if you do your part right.

Storing Explosives and Supplies

The storing of dynamites and powders on farms offers no serious problems, though it may call for some shifting of arrangements to meet proper requirements. The explosive must be kept dry. They should be kept cool. This means that any ordinary temperature of the air is all right, except that in hot weather the room where the explosive is kept should not get warmer than 80 or 90 degrees. If it is properly ventilated day and night it will not. Probably the best common storage place for explosive is in an outbuilding under the floor of which the air circulates freely and with a ceiling between the room and the roof. It should be strong, and should be provided with a lock. A responsible person should have charge of the key at all times.

The explosive should not be kept in a garret, because the hot sun beating down on a roof will raise the temperature under the roof away past the 100 degree mark.

Dampness is injurious to explosives, as noted on page 44, and dynamites and powders must be kept where moist air will not surround them. The ideal storage would be fireproof, but since this is out of the question on the average farm, the best that can be done in that respect is to guard against fire. It is well to make sure that the explosive is out of reach of any stray or malicious bullet that might be fired into it.

Look to your insurance policies and see whether they provide against the storage of explosives in any of your buildings. Store the explosive in a building not covered by the insurance.

Where large quantities of explosives are to be stored as a regular thing, or for any length of time, it is advisable to consult the makers of explosives or others experienced in their handling in regard to the location and construction of a magazine. A magazine can be set up cheaply and can be made fireproof, bullet proof, thief proof, well ventilated, dry and safe in every way. It should be built of brick. Any explosive maker will furnish plans without charge. In any case explosives should be stored at least 50 yards away from any other buildings and from roads or railroads.

Magazines

Blasting caps of any kind must not be stored with dynamite or powder. Fuse is not explosive and can be stored with dynamite or powder.

Caps

Blasting caps are even more subject to damage by moisture than explosive and must be stored accordingly. Caps must not be allowed to become heated.

A statement of the ways in which explosive deteriorates will help in selecting a proper storage place for it. In temperatures higher than 80 degrees troubles may begin. Long continued temperatures of 90 to 100 degrees may cause the nitroglycerin to leak out of the absorbing material and to gather inside the wrapping on the lower side of the sticks, or may even cause it to leak out of the wrappings through the boxes and to the floor.

Deterioration

Strict watch should be kept of the sticks and the boxes to catch any such condition. If leakage occurs, turn the explosive over and reduce the temperature. Burn the empty boxes one or two at a time out away from buildings, and scrub the floor where the leakage occurred with a strong solution of sal soda. This will decompose the nitroglycerin. If it becomes necessary to destroy a little explosive without detonating it, the job can be done by immersing it until dissolved in such a solution, stirring it gently with a wood paddle.

If the sticks feel smeary it is possible they are leaking. The test is to lay them on white paper for a little while. If they are leaking they will stain the paper, otherwise not.

At a temperature of 105 degrees nitroglycerin explosives will lose 10% of their strength in a few days by evaporation. Repeated freezing and thawing is bad for explosives, especially if the thawing is rapid. Slow thawing will not damage them much. After explosive once is frozen and thawed, it will freeze much easier again.

When stored for many months explosives are liable to decomposition of some of their elements, especially if they get damp or too warm. One of the marks of this is greenish stains inside the stick wrappings. No length of time can be stated for the keeping of explosives, because it practically all depends on conditions. Under favorable conditions most dynamites and powders will remain in good shape for years. Again, a month of improper storage will ruin them and make them dangerous to handle. They develop troubles sooner in the light than in the dark.

Deteriorated explosives are likely to be dangerous—far more so than normal explosive. Keep watch over what you have in stock. Maintain proper conditions as far as possible, but if they show troubles do not hesitate to condemn them.

Shipping Explosives

The shipping of high explosives is controlled by the Interstate Commerce Commission, and the rules and regulations are very strict and rigid. Most of them are embodied in an Act of Congress of March 4, 1909, and violations are punishable with fines of not more than $2,000, or imprisonment for not more than eighteen months, or both. The person making the shipment is responsible.

A copy of the rules and regulations can be secured from the Bureau of Explosives, Underwood Building, New York City, or can be read at any freight station where there is an agent.

The rules provide that no explosives (other than certain exceptions named) shall be carried on any train, boat, trolley, or other vehicle carrying passengers

for hire, and that no explosives under deceptive or false markings or understanding shall be delivered to a common carrier; and further, that all other regulations shall be complied with.

In shipping by railroad no caps or detonators of any kind can be sent in the same car with explosives. In practice the railroads usually send them by another train, which works out to be another day in the cases of nearly all shipments. This is responsible for some delay in delivery of explosive shipments. Do not expect to have explosives come through as quickly as you would other freight.

Explosives cannot be shipped by express or by mail, but are sent by freight, the same as groceries or dry goods. The railroad company is required to place the packages in a certain way inside the car and to brace them with lumber. In case of car-lot shipments the shipper must furnish this lumber and do the bracing.

The regulations provide that railroads must have 24 hours' notice of shipment of explosives, *and that shipments must be removed from the receiving station within 24 hours of their arrival there.* The packages must be plainly stenciled with the name of shipper and consignee, and bills of lading must conform with certain specifications.

Empty boxes which once have contained explosives must never again be used for shipments of any kind. Farmers who have attempted to ship vegetables or other farm products in such boxes have unwittingly gotten themselves into trouble on account of this regulation more than once.

Danger and Safety

Modern explosives have been developed to the point where they need not be feared by anyone who handles them intelligently. Speaking in a comparative way, they may be used with no greater dangers than there is in the using of horses, mowers, traction engines, sawmills, or other farm equipment, or than there is in using shotguns or rifles.

The general use of explosives on farms is so new that many people distrust them more because of their newness than from a clear understanding of any actual dangers their use may hold. A review of what the dangers are may help users of explosives to avoid them, and may help to build up the reader's belief in the *safety* of explosives.

There is some danger in the handling and transporting of explosives, but it depends very largely on the exposure of the dynamite or powder to heat, flame, sparks, blows and friction. The directions say to keep explosives dry, to keep them at a temperature less than 90 or 100 degrees F., to keep them safe from sparks, and to avoid blows and shocks. If these directions are followed there will be few accidents.

Probably the most common cause of accidents with explosives lies in violation of some of these primary rules while thawing frozen sticks of dynamite or powder. Freezing makes the high explosive less sensitive to the simple direct shock of a blasting cap, unaccompanied, as it is, by any friction. But at the same time freezing makes the explosive more sensitive to friction in any form.

For this reason, though a frozen stick of dynamite cannot be fired properly by a blasting cap, it is very likely to be fired prematurely by a chance light blow from any object touching it, by your slitting the wrapping paper with a knife, by breaking the stick in two, or by attempting to punch a hole into it to insert a cap. (These operations are entirely safe when the explosive is normal.) If the stick is dipped in warm water or exposed to steam, or is laid on anything which is warmer than about 125 degrees, free nitroglycerin likely will leak out

and fall in drops. And one drop of nitroglycerin falling only a few inches may be exploded itself and may explode all dynamite that is near it.

Throughout the entire course of handling the explosive, from the freight station to the hole in the stone or the ground, you should remember the five cautions which will be repeated: Keep it dry, keep it cool, keep it away from sparks and flame, and keep it safe from blows and friction. Be careful—as careful as you would in driving a big automobile or a traction engine. Then you will be secure from any accidents, and explosives will be entirely safe to handle.

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